NOTICE

All drawings located at the end of the document.

TRU Waste

TRU waste is defined as any waste contaminated with alpha-emitting transuranic radionuclides with half-lives greater than 20 years and in concentrations greater than 100 nanocuries per gram (nCi/g). TRU waste was generated as a result of the nuclear weapons component production process and continues to be generated as a result of routine operations, DD&D activities, and the Residue Stabilization Program (Kaiser-Hill 1995c).

TRU waste at the Site is primarily contaminated with plutonium and americium. All of this waste is categorized as contact-handled waste, which means that 1) the package surface dose rate is no greater than 200 millirem per hour, 2) no additional shielding of the waste is required, and 3) the waste can be handled directly by personnel using standard protective equipment. TRU waste forms include combustibles, sludges, plastics, light metals, and liquids.

The 1996 inventory of stored TRU waste was approximately 770 cubic meters. TRU waste is being generated at the rate of approximately 27 cubic meters per year. Facilities available for the treatment and packaging of TRU waste include the size reduction vault, the advanced size reduction vault, and the supercompaction and repackaging facility.

TRU waste generated at the Site prior to 1970 was shipped to the Idaho National Environmental Engineering Laboratory (INEEL) for disposal. After 1970, this waste was shipped to INEEL for interim retrievable storage pending development of a permanent disposal facility. As a result of delays in opening the WIPP facility in New Mexico, the State of Idaho in October 1988 has prohibited the interstate transportation of further waste shipments from the Site, forcing the Site to continue storing TRU waste. To date, no disposal alternative exists for TRU waste, but the WIPP continues to be the only facility that will be made available in the near future. Some processing (such as immobilization, neutralization, oxidation, and repackaging) would be necessary before some TRU waste could be shipped to the WIPP.

TRU-Mixed Waste

TRU-mixed (TRUM) waste is TRU waste that contains RCRA-regulated hazardous constituents. In the past, TRUM waste was managed similarly to TRU waste in that it was shipped to the INEEL for disposal or interim storage prior to October 1988. Currently, it is stored on-site. Storage of TRUM waste is permitted by CDPHE and is limited to 1,225 cubic meters. The 1996 inventory was approximately 560 cubic meters, and TRUM waste continues to be generated at a rate of approximately 27 cubic meters per year. Facilities available for the treatment and packaging of TRUM waste include the size reduction vault, the advanced size reduction vault, and the supercompaction and repackaging facility.

As with TRU waste, no disposal capabilities exist or are planned at the Site, and off-site disposal is contingent on the availability of WIPP. Recent legislation allows for land burial of TRUM waste that does not meet RCRA land disposal restrictions. Therefore, no treatment other than that required to meet the WIPP waste acceptance criteria would be required for TRUM waste. This treatment could potentially include immobilization, neutralization, oxidation, and repackaging (Kaiser-Hill 1995c). The draft Site Closure Plan calls for shipment of TRU & TRU-mixed waste to INEEL for treatment beginning in fiscal year 2004.

In preparation for waste shipment to the WIPP, several waste characterization and classification programs are in progress for TRU and TRUM waste. Drums are being vented and aspirated (a process that filters and releases gases that have accumulated in the headspace of unvented waste containers). Characterization activities required for waste certification are in progress, including real-time radiography, nondestructive assay, headspace gas sampling, organic gas analysis, and inorganic gas analysis. Gas generation studies required to qualify additional waste categories for shipment to the WIPP are also being performed.

Hazardous, Toxic, and Medical Waste

At the Site, the principal types of nonradioactive regulated waste are hazardous, toxic (regulated under TSCA), and medical waste. Hazardous waste is any solid waste defined as hazardous by EPA in the RCRA regulations or by CDPHE in the Colorado Hazardous Waste Act (CHWA) regulations. Hazardous waste includes solid waste that either exhibits hazardous characteristics or is named on one of the lists developed by EPA or CDPHE. Examples of hazardous waste include paint thinner and lead-contaminated soil. Radioactive wastes that contain hazardous constituents fall within the definition of hazardous waste but are classified as mixed waste; these waste types are discussed in the LLMW, TRUM waste, and residues sections.

As of 1995, CDPHE had permitted 512 cubic yards of hazardous waste storage space at the Site. The 1996 inventory was approximately 270 cubic meters. Hazardous waste continues to be generated at a rate of approximately 80 cubic meters per year. Hazardous waste is collected at the point of generation, primarily in 55-gallon drums. Full drums are labeled and transported to 90-day storage areas, where weekly inspections and other requirements are conducted in compliance with CHWA. Prior to expiration of the 90-day period, drums are moved to a RCRA storage unit where they are prepared for off-site shipment to a commercial facility for treatment and disposal.

Most of the hazardous waste inventory at the Site consists of granular activated carbon, soils, debris, and structural materials generated by environmental restoration operations. The remainder consists of combustibles, equipment, and metals generated from routine operations supporting facility maintenance, waste stabilization and management, and SNM management.

TSCA-regulated waste is present in two forms at the Site: asbestos and PCBs. Asbestos and PCB waste that contain no other contaminants is shipped to commercial sites for treatment and disposal. Radioactive PCB waste is placed in a radioactive storage area pending treatment and disposal. There are currently no DOE or commercial facilities that can accept the Site's radioactive PCB waste for disposal. The 1996 inventory of PCB waste was approximately 18 cubic meters.

Low-level asbestos waste (asbestos waste with a radionuclide concentration not exceeding 100 nCi/g) is stored in a radioactive waste storage area before shipment to DOE's Hanford, Washington facility for disposal.

Medical (infectious) waste consists of any solid waste generated from the diagnosis, treatment, or immunization of humans or animals. Infectious waste may include cultures and stocks of infectious agents, human pathological waste (such as tissues and body parts), human blood and blood products, contaminated sharps (such as hypodermic needles and syringes), and certain isolation waste (such as waste from patients with highly communicable diseases).

No inventory of medical waste currently exists, and approximately 5 cubic meters per year is expected to be generated. The following organizations at the Site generate medical waste: Occupational Health (Building 122), Health Physics (Building 123), and the Rocky Flats Fire Department. This waste is treated according to EPA-approved methods to render it non-infectious (at the Site, either chemically treated or sterilized), then disposed of as sanitary waste at the on-site sanitary landfill (Kaiser-Hill 1995c and DOE 1994a).

Sanitary Waste

Sanitary waste (also called municipal and industrial solid waste) includes waste generated at the Site that is not radioactive or regulated. Both waste water and solid waste streams are generated.

Sanitary waste water is collected in a system connected to all major buildings at the Site and conveyed to Building 990 for flow equalization and regulation. From Building 990, the water flows to the on-site waste water treatment plant in Building 995 for treatment. Treatment of sanitary waste water generates two products: treated water and sewage sludge. Treated water is

OU1 (881 Hillside)	OU9 (Original Process Waste Lines—Industrial Area)
OU2 (903 Pad, Mound, and East Trenches)	OU10 (Other Outside Closures—Industrial Area)
OU3 (Off-Site Releases)	OU11 (West Spray Field)
OU4 (Solar Evaporation Ponds)	OU12 (400/800 Area—Industrial Area)
OU5 (Woman Creek Drainage)	OU13 (100 Area—Industrial Area)
OU6 (Walnut Creek Drainage)	OU14 (Radioactive Sites—Industrial Area)
OU7 (Present Landfill)	OU15 (Inside Building Closures)
OU8 (700 Area—Industrial Area)	OU16 (Low-Priority Sites)

Figure 2-4 shows the location of these operable units prior to 1996. The number of operable units has been reduced by RFCA to two—one for the Buffer Zone and the other for the Industrial Area. CDPHE is the lead regulatory agency for cleanup in the Industrial Area, while EPA is the lead regulatory agency for cleanup in the Buffer Zone.

Attachment 4 in RFCA contains the 1995 prioritized list of IHSSs. The list was generated to be utilized as a tool in planning and prioritizing remedial actions at the Site. In accordance with RFCA, Attachment 4, the ranking has been updated for 1996, and has been modified to incorporate the Action Level Framework (ALF) (RFCA, Attachment 5) and process knowledge. This ranking was developed utilizing concentrations of contaminants present at different sites, action levels for appropriate media and location, and factors for impact to surface water, potential for further release, and professional judgment to develop a score for each site. The scores were then ranked to determine which sites have the highest priority.

The Annual Update to the Historical Release Report (HRR) is a document that provides a variety of information pertaining to spills, releases, or findings of contaminants at the Site. In accordance with RFCA, spills releases, or findings which require notification in the HRR are identified as Potential Areas of Concern (PACs) and are described in a format consistent with the original HRR submitted in 1992, and were updated quarterly between 1992 and 1995. The original purpose of the HRR was to capture existing information on historical incidents involving hazardous substances at the Site and continue the reporting process for current incidents involving the release of hazardous substances.

The environmental restoration program at the Site includes conducting soil, sediment, ground water, and surface water sampling to further characterize the nature and extent of contamination, operating ground water and surface water treatment systems, and excavating contaminated source areas. Environmental restoration ground water and surface water treatment systems in operation as of June 1996 include those for 881 Hillside, the 903 Pad, and the Solar Evaporation Ponds. These systems are briefly described below.

1. At the 881 Hillside location, contaminated ground water is collected via an underground drainage system (French drain) and one collection well, and transferred to Building 891 for treatment. This process removes radionuclides, heavy metals, alkalinity, volatile organic compounds, and dissolved solids and treats the ground water for hardness. After treatment and testing, the water is released on-site into the South Interceptor Ditch. Water collected from this ditch undergoes a secondary analysis prior to release. Environmental restoration activities at the 881 Hillside location are being conducted in accordance with a Record of Decision executed for OU1 in March 1997.
2. The 903 Pad surface water treatment system consists of collection and treatment of surface water from a seep near South Walnut Creek. Surface water is collected at one location and pumped to the treatment facility in Building 891.

Routine, periodic surveillance activities are undertaken to monitor the condition of facilities containing radioactive or hazardous material in order to maintain them in a safe condition and to detect conditions that could lead to a release of radioactive or hazardous substances to the environment. Examples of surveillance activities include routine radiological measurements, physical inspections, and fire watches.

Emergency Response

The Site's emergency preparedness program interfaces with federal, state, and local government agencies and private organizations for response to emergency situations. Response measures are designed to protect the health and safety of on-site personnel and the public, limit damage to facilities and equipment, minimize impacts to on-site operations and security, and limit adverse impacts to the environment in the event of:

- Fire or explosion
- Hazardous or radioactive material releases
- Nuclear criticality
- Security-related events (e.g., bomb threats, civil disturbance, extortion, hostage-taking, sabotage, and hostile attack)
- Events related to nuclear material safeguards and threats to vital equipment
- Transportation accidents
- Natural phenomena

The Emergency Response organization is designed and staffed specifically to manage response efforts in the event of an operational emergency. Drills and exercises are conducted at the Site to develop, maintain, test, and evaluate the response capabilities of emergency response personnel, facilities, equipment, procedures, and training under simulated emergency conditions.

The Site's Fire Department is located in Building 335. In addition to providing emergency response, Fire Department personnel perform fire extinguisher servicing, conduct fire extinguisher training, and perform inspections.

Maintenance

Maintenance services include the like-for-like replacement of equipment and parts, minor upgrades to more modern equipment, cleaning and upkeep of buildings (e.g., window washing, mowing, trash collection, and painting), fabrication of fixtures and parts, and repair and maintenance of DOE vehicles.

Maintenance shops are located throughout the Site. Paint shops handle all on-site painting, grit blasting, sand blasting, and engraving activities. Electrical shops handle general maintenance of electrical equipment, including changing electrical fixtures, servicing rechargeable batteries, and repairing power tools, electric carts, forklifts, and vertical lifts.

Custodial and maintenance areas use a variety of solvents and detergents for cleaning and upkeep of all buildings on the Site. Lubricants, coolants, parts, fittings, sheet metal, and pipes are used in routine maintenance of machinery, equipment, and support systems.

In the fabrication shops, metals and other materials are machined and milled to create fixtures and parts such as ventilation ducts, piping, cabinets, boxes, room dividers, shelves, and tables for use in all areas of the Site. The fabrication shops include the carpentry, pipe, machine, sheet metal, and iron-working shops for activities that take place in Buildings 130, 334, 371, 460, 553, 776, 778, 779, 780, 881, and 980.

The Integrated Chemical Management System provides mechanisms for direct and ancillary chemical management. Examples of direct chemical management include tracking of chemicals, identification of excess chemicals, identification of reactive chemicals, and bar-code scanning of chemical containers. Examples of ancillary chemical management include reporting of potential chemical hazards to emergency response organizations, profiling of hazardous chemicals for Industrial Hygiene and other medical organizations, providing a central database of chemicals approved for purchase at the Site, and consolidating information for Superfund Amendments and Reauthorization Act "Community Right-to-Know" requirements. Ancillary chemical management also involves support for Clean Air Act Title V operating permit requirements and identifying potential hazards for fire fighting and emergency response planning.

WAREHOUSING. The warehousing function includes receipt of deliveries, quality inspection of deliveries, and materials storage. Building 130 is the primary receiving and distribution warehouse for the Site. Building 551 is used for storage and distribution of office supplies. Items designated for sale at auction or donation to schools or other entities are stored in Building 61.

PROPERTY UTILIZATION AND DISPOSAL. The disposition of federal property is governed by specific criteria for priority of disposal, sale, or recycling. In addition, before material can be moved off-site, it must be screened for radiological or chemical contamination and evaluated as excess or suitable for recycling. The Property Utilization and Disposal organization operates the property utilization and disposal yards at the Site.

The largest yard is located near the sanitary landfill and firing range northwest of the Industrial Area. The yard in the Protected Area is located between Buildings 964 and 965. A number of smaller yards are located throughout the Site, including those that contain excess, scrap, or bulk materials awaiting disposition.

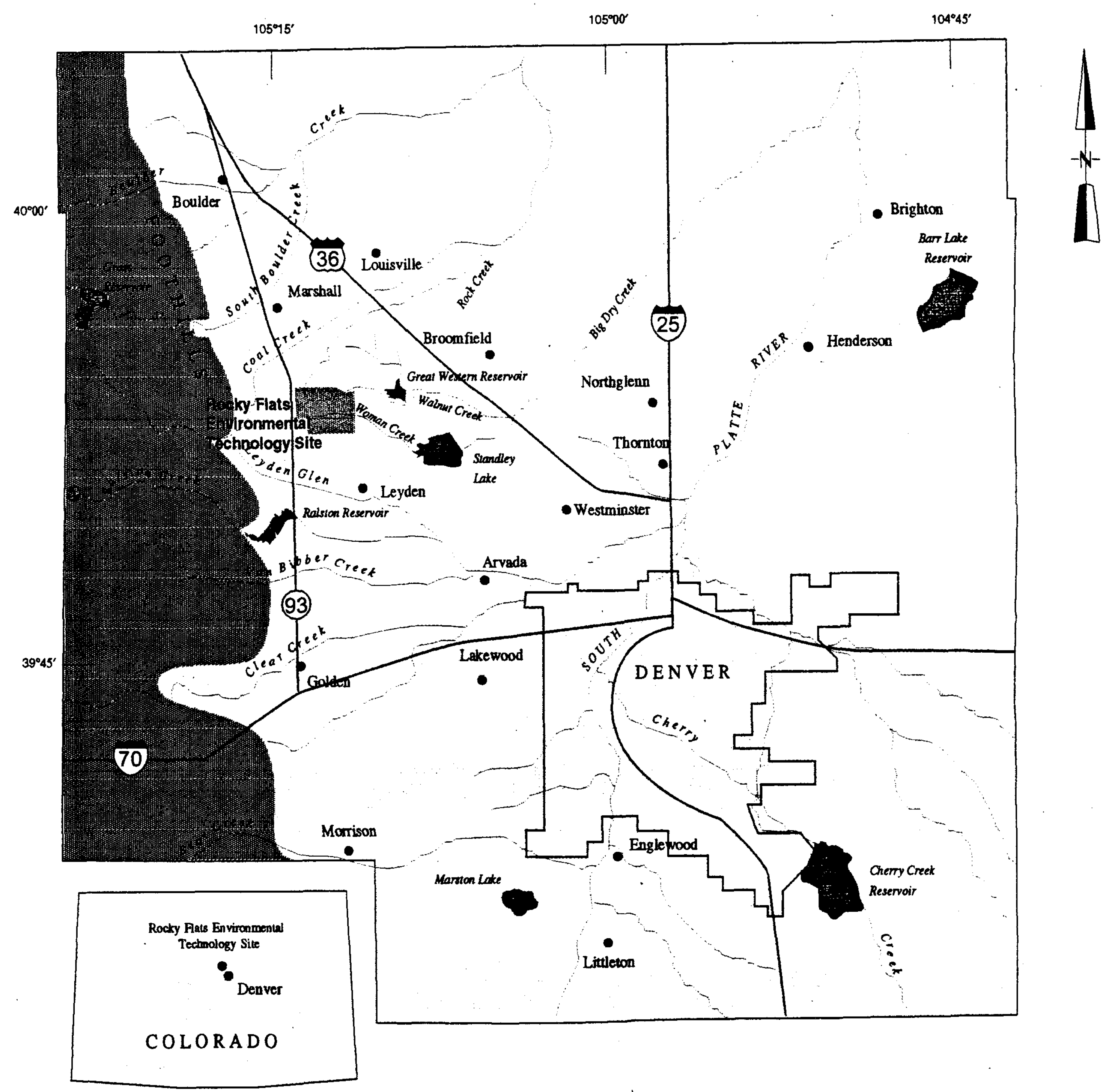
Site-Wide Monitoring

Sampling and monitoring activities provide information on the presence, nature, extent, fate and transport of contaminants in soils, sediments, surface water, and ground water. Monitoring programs are discussed in their respective media sections (e.g., "Soils," "Water," "Air") and are briefly summarized below. Routine reports to federal, state, and local agencies and to the public provide information on Site environmental monitoring programs.

Soil sampling is conducted at 40 sampling locations within two concentric circles approximately 1 and 2 miles from the center of the Site. Data is used to evaluate changes in plutonium concentrations that might occur through soil resuspension or other mechanisms, and to compare plutonium concentrations in soils on an annual basis.

Surface water quantity and quality are monitored via a gauging station network located in the Buffer Zone and Industrial Area. The gauging stations monitor flow through detention ponds and diversion structures and runoff from major tributaries (primarily Walnut Creek and Woman Creek) and the Industrial Area. Surface waters at the Site are analyzed extensively for radionuclides, organics, metals, and other constituents in accordance with specific regulatory requirements to ensure compliance with water quality standards, to characterize background water quality, and to evaluate potential contaminant releases from specific locations.

The ground water monitoring program uses a network of wells and piezometers to characterize ground water quality and hydrogeology. The program provides information on the presence, nature, areal extent, fate, and transport of contaminated ground water. As of the end of 1996, approximately 1,000 wells existed at the Site, 152 of which are sampled on a regular basis in accordance with the groundwater monitoring program. Samples are analyzed for metals, organics, radionuclides, anions, and other specific parameters. Quarterly water-level measurements are also recorded to evaluate ground water flow directions.



0 5 10 Miles

U.S. DEPARTMENT OF ENERGY
Rocky Flats Environmental Technology Site
Golden, Colorado

Location of Rocky Flats Environmental Technology Site

Figure 2-1

Best Available Copy

395\ES\SWEIS\RFP & Vic. Map-3004.II

ROCKY FLATS ENVIRONMENTAL TECHNOLOGY SITE CUMULATIVE IMPACTS DOCUMENT (CID)

EXECUTIVE SUMMARY

The Cumulative Impacts Document (CID) for the Rocky Flats Environmental Technology Site (Site) has been prepared to provide an updated baseline of the cumulative impacts to the worker, public and environment due to Site operations, activities, and environmental conditions in light of the Site's change in mission. Specifically, the Site has gone from production of nuclear weapons components to materials and waste management, accelerated cleanup, reuse and closure of the Site. The CID serves as an updated baseline of activities and associated environmental impacts reflected in the April 1980 *Final Environmental Impact Statement for the Rocky Flats Plant Site* (DOE 1980).

In addition, this document projects the cumulative impacts to the worker, public and environment due to implementing the Site's draft Site Closure Plan, dated February 1997. The draft Site Closure Plan is a planning tool for achieving accelerated cleanup and closure of the Site. The draft Site Closure Plan also includes the planning assumptions which are expected to reduce the overall site risks to the worker, public, and environment.

Contents of the CID

The CID consists of five chapters, three appendices, and a bibliography. Chapter 1 provides an introduction which explains the purpose and scope of the CID as well as providing the overall context of the CID relative to other planning and regulatory activities at the Site. Chapter 2 describes the Site's location, background, and operational activities. Chapter 3 outlines the *baseline* and *closure* cases and the various elements that are examined by the CID. Chapter 4 includes a comprehensive presentation of the Site's environmental baseline (geology, soils, water, air, traffic and transportation, utilities, human health and safety, ecological resources, noise, socioeconomics, and environmental justice) and provides the context for understanding the environmental impacts described in Chapter 5. The appendices contain the data and information relied upon in Chapter 5.

Description of CID Cases

Two cases are analyzed in this CID in order to determine the cumulative impacts to the worker, public and environment relative to the Site's activities over the draft Site Closure Plan timeframe. The project specific information outlined in Chapter 3 for each of the Site's major programs forms the basis for the impacts assessed in Chapter 5. The five major programs are Special Nuclear Materials (SNM) Management, Facility Disposition, Waste Management, Environmental Restoration and Site Support Services.

Following is a general description of the major activities expected to occur under each case. The *baseline* case reflects the Site's condition as of December 1996. The *closure* case represents Reference Case 2 of the Site's draft Site Closue Plan dated February 1997.

BASELINE CASE

Under the *baseline* case, the SNM consolidation in B371 was 60% complete as of December 1996, with all backlog plutonium (Pu) metal and oxide stabilized and repackaged. Some treatment of solid residues has occurred and residues are stored in existing facilities. Stabilization of liquid

1. dispersible residues (ash, some wet combustibles, some salts);
2. plutonium oxide (due to previous SNM consolidation efforts);
3. plutonium hold-up;
4. TRU waste in metal drums resulting from residue stabilization,
5. plutonium metal (eliminated from contribution to releases after packaged in DOE Standard 3013 welded containers);
6. other TRU/TRUM waste in metal drums (existing inventory plus future generation by DD&D); and
7. Low-level and low-level mixed (LL/LLM) waste.

- The *closure* case reveals that as residue stabilization and repackaging activities are started in Building 707 there is a slight increase in risk, due to accidents, to the public and to co-located workers in the near term. Risks drop as Building 771 and 776 SNM and residues are recovered from the site. When the residues are repackaged and SNM is moved to the new Interim Storage Vault (ISV), risks from accidents decrease significantly (about a factor of 10), and then steadily decrease as Pu holdup is removed during DD&D. The risk from fires involving LL wastes in wooden boxes then dominate risk until the year 2012 when all LL wastes and TRU waste shipments are completed, resulting in another three orders of magnitude reduction in risks from accidents. Risk to the public after this time would be due to material handling accidents in the new ISV.

- The following closure operations and activities contribute the most to reducing the risk of accidents caused by seismic events and thereby overall accident risk to the workers, co-located workers and public in the following order of priority based on projected schedules:

  1. consolidating plutonium oxides into building 371;
  2. repackaging the dispersible residues into the pipe/drum component or storing in building 371;
  3. removing plutonium hold-up;
  4. shipping TRU/TRUM waste drums to WIPP;
  5. transferring SNM from building 371 to the ISV or shipping off-site;
  6. shipping other TRU/TRUM waste to WIPP; and
  7. shipping LL/LLM waste off-site.

- Risks to the public from hazardous chemical accidents is low. However, risk to facility workers and co-located workers could be significant if effective emergency response plans are not implemented. The chemicals that dominate the non-radiological accident risks are ammonia, chlorine, sulfur dioxide, nitric acid and propane.

- Operations and activities that result in an increase in risk to the workers, co-located workers and the public from normal operations with little resulting short term risk reduction benefit are as follows:

  - DD&D facilities after Pu hold-up is removed or a fixative is applied; and
  - remediation activities.

- The CID provides a comparative summary of the two cases in terms of their expected environmental impacts (see, Chapter 5, Table 5.1-1). The following are some insights gained from the ecological risk assessments and impacts analysis relative to the environment.

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and closure activities reflected in the draft Site Closure Plan, will continue to meet its NEPA obligations by relying on appropriate project specific categorical exclusions, environmental assessments, and environmental impact statements. In addition, the Site will incorporate NEPA values into environmental restoration and decommissioning decisions prepared pursuant to the Rocky Flats Cleanup Agreement (RFCA) and CERCLA. The CID will not contain any formal Records of Decision (ROD) that are customarily found in Environmental Impact Statements.

The scope of this CID is to provide a recounting of the Site's updated *baseline* and *closure* case activities and the relative impacts of these activities to the worker, public, and environment. The CID, therefore, is focused specifically on *baseline* and *closure* activities at the Site which are initiated by or sponsored through resources of DOE and its contractors. The CID will not describe or otherwise analyze the potential impact to Site operations or its cultural and natural resources of privately owned and operated sand and gravel quarry operations located in the northwest portion of the Buffer Zone.

1.2 Definition of Cumulative Impacts

For purposes of the CID, cumulative impacts are the incremental effects of an action or actions when added to other past, present, and reasonable foreseeable future actions carried out both by the federal agency and other entities within the geographical region. Significant impacts can result from several smaller actions which, by themselves, may not have significant environmental impacts.

This document, describes the cumulative impacts that are a result of our current Site mission, operations and activities as of December 1996 (*baseline* case) and the cumulative impacts as a result of implementing the draft Site Closure Plan assumptions (*closure* case). Therefore, the cumulative impacts will be calculated by adding up the impacts resulting from the Site's five major program operations and activities to the impacts from potential off-site projects in the vicinity of the Site. Chapter 5 summarizes the cumulative impacts resulting from the *baseline* and *closure* cases combined with the impacts from potential off-site projects impacts.

1.3 Relationship of CID to Other Planning and Regulatory Activities

A number of planning and regulatory documents affect the Site's operations and activities, including a Vision Statement - a guide to activities at the Site; the Rocky Flats Cleanup Agreement—the legal process for cleanup at the Site; and the draft Site Closure Plan—the planning tool for closing the Site. A description of these three interrelated documents and how they are addressed in the CID is provided below.

Vision Statement[1]

Stakeholders and the cognizant federal and state agencies have signed a Vision Statement to guide Site activities and to set future Site expectations for the broader community. The Vision Statement provides a road map for a common course of actions in response to consensus goals developed in collaboration with the community. All activities, agreements, planning documents, and other legal arrangements are being guided by this Vision Statement and are to preserve, to the fullest extent possible, the full range of options and opportunities necessary to

[1] *Vision Statement was signed July 19, 1996 and is an appendix to RFCA.*

5. *At a minimum, given existing technology and resources, the Site will be cleaned up to allow open space and other appropriate uses. Where possible, the Site will be cleaned up to the maximum extent feasible. Should cost-effective technologies and additional fiscal resources become available, a goal of achieving average background levels of contamination for the Front Range of Colorado will be supported. The Site's unique ecological values will be preserved.*

   DOE is committed to assuring monitoring and maintenance of any waste or contamination remaining on-site, the containment of contamination, and allowing for the further treatment of waste as new and emerging cost-effective technologies become available. In addition, because the Site contains a unique ecological habitat that cannot easily be replaced, its ecological values will be preserved and protected to the maximum extent possible during cleanup and closure activities.

6. *The future uses for the Site will be decided with the full and active involvement of local governments and the public. Cleanup and closure activities will support a wide range of appropriate future uses.*

   This anticipates that the Site will be cleaned up so that it can be used as open space or converted to other appropriate uses consistent with community preferences, although opportunities for residential use may be limited.

The programs analyzed in this CID reflect varying levels of activity to achieve the goals of the Vision Statement.

Rocky Flats Cleanup Agreement

The Rocky Flats Cleanup Agreement (DOE 1996i) is a legal document that describes a process for regulatory decision-making at the Site. It replaces the 1991 Federal Facility Interagency Cleanup Agreement and describes the relationship between the signatory agencies—DOE, the U.S. Environmental Protection Agency (EPA), and the Colorado Department of Public Health and Environment (CDPHE)—during cleanup. The Rocky Flats Cleanup Agreement provides the regulatory framework to facilitate achieving the goals set forth in the Vision Statement.

One of the Rocky Flats Cleanup Agreement's goals is to create a "single regulator" approach, using one set of consistent environmental requirements and a process for reaching specific decisions within targeted timeframes. The document describes the roles and responsibilities of each of the parties and mechanisms for implementing those responsibilities. It provides a legal framework for making individual cleanup and waste management decisions for environmental restoration without predetermining those decisions.

The Rocky Flats Cleanup Agreement does not govern the management of SNM or residues, nor does it govern the management of buildings deactivation and decontamination for future DOE use. The Defense Nuclear Facilities Safety Board (DNFSB) will continue oversight of these activities. Further, the management of process waste and other Site support activities will be governed by the Colorado Hazardous Waste Act, the Resource Conservation and Recovery Act (RCRA), the Clean Air Act, the Clean Water Act, the Toxic Substances Control Act (TSCA), and other environmental laws outside of the Rocky Flats Cleanup Agreement.

The purpose of the Rocky Flats Cleanup Agreement ensures a cooperative effort to promote a cost-effective, safe cleanup of the Site. There are eight specific RFCA objectives agreed upon by the participating agencies. They include:

will achieve accelerated cleanup and closure of the Site and rapidly reduce the risks to the Site workers, the public, and the environment.

The CID *closure* case reflects the Site's draft Site Closure Plan assumptions for "Reference Case 2" and analyzes the environmental impacts and risks based on these assumptions.

1.4 Relationship of CID to Site NEPA Strategy

The NEPA Strategy for the Site as it undergoes key cleanup and closure activities reflected in the draft Site Closure Plan is to rely on project specific NEPA and CERCLA documents as is appropriate. The CID, which contains an updated baseline of the cumulative impacts to the worker, public and environment due to Site operations, activities, and environmental conditions reflective of the current Site mission, complements the Site NEPA strategy by making this information readily available to be referenced in future decision making.

Many of the key cleanup and closure decisions facing the Site at this time are in fact complex-wide decisions. These decisions must be made in the context of broader Programmatic Environmental Impact Statements (PEIS). Six DOE NEPA reviews currently under way or already completed form the basis for decisions that could affect the Site. The six Environmental Impact Statements are:

- *Storage and Disposition of Weapons-Usable Fissile Materials Programmatic Environmental Impact Statement*
- *Environmental Impact Statement for the Continued Operation of the Pantex Plant and Associated Storage of Nuclear Weapons Components*
- *Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste*
- *Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada*
- *Supplemental Environmental Impact Statement: Waste Isolation Pilot Plant*
- *Interim Storage of Plutonium at Rocky Flats Environmental Technology Site Environmental Impact Statement*

Storage and Disposition of Weapons-Usable Fissile Materials Programmatic EIS

The *Storage and Disposition of Weapons-Usable Fissile Materials Programmatic EIS* (DOE 1996b) presents an assessment of alternatives for long-term storage and disposition of DOE weapons-usable fissile materials including plutonium. This Programmatic EIS was designed as a means of establishing national policy for management of these materials and focuses on long-term solutions to storage and disposition issues of weapons-usable fissile materials. It includes supporting decisions on the long-term storage of plutonium pits[2].

DOE issued a decision that pits will be stored at the Pantex Plant in Amarillo, Texas. In addition, the Savannah River Site (SRS) in South Carolina, has been identified as the long-term storage site for the Department's plutonium metal and oxide inventory. A Record of Decision (ROD) was issued January 1997 and reflects Departmental decisions to transport pits

[2] *Pit: The central core of a nuclear weapon containing plutonium-239 and/or highly enriched uranium that undergoes fission when compressed by high explosives. The pit and the high explosive are known as the primary of a nuclear weapon.*

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The DOE is preparing an *EIS on Management of Certain Plutonium Residues and Scrub Alloy Stored at the Rocky Flats Environmental Technology Site,* that is evaluating alternatives for processing those residues which require further treatments in order to allow disposal at WIPP. A ROD is expected in November 1997, and is anticipated to evaluate treatments for residues which will support the *closure* case of removing residues from the Site.

Interim Storage EIS

A notice of intent to prepare an EIS on construction of an interim storage vault was published on July 17, 1996. Recent decisions resulting from the storage and disposition of weapons usable fissile materials PEIS have resulted in the suspension of preparation of the interim storage EIS. A notice of cancellation of the interim storage EIS will be published.

Relationship to Site Environmental Assessments

The following NEPA planning documents have been developed for actions at the Site since the end of 1994.

- Consolidation and Interim Storage of Special Nuclear Materials Environmental Assessment (DOE 1995l)
- Rocky Flats Solid Residue Treatment, Repackaging, and Storage Environmental Assessment (DOE 1996c)
- Rocky Flats Actinide Solution Processing Environmental Assessment (DOE 1995k)
- Radioactive Waste Storage Environmental Assessment (DOE 1996d)
- Surface Water Drainage System Environmental Assessment (DOE 1996o)
- Rocky Flats Protected Area Reconfiguration Environmental Assessment (DOE 1995p)
- New Sanitary Landfill Environmental Assessment (DOE 1994b)
- Draft NCPP Stage III Environmental Assessment

Findings Of No Significant Impact (FONSI) have been issued for each of these environmental assessments.

These NEPA documents provide an analysis of activities which may potentially impact future decisions made at the Site with respect to special nuclear materials management, waste management, and other activities. The relative impacts for these actions are accounted for in the cumulative impacts assessment for both the *baseline* and *closure* cases in the CID.

1.5 Preview of Chapters

The information presented in the remaining chapters of the CID is summarized below.

- *Chapter 2* describes the activities and programs that define current Site operations and activities
- *Chapter 3* describes the *baseline* and *closure* cases analyzed in the CID
- *Chapter 4* describes the environment as it exists under *baseline* conditions
- *Chapter 5* provides the impacts and consequences of both the *baseline* and *closure* cases and describes the cumulative impacts resulting from the *baseline* and *closure* cases combined with potential off-site projects in the vicinity of the Site

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CHAPTER 2
BACKGROUND

2.1 Introduction

This chapter presents background information, including an overview of the historical and current missions of the Rocky Flats Environmental Technology Site (Site), its location, and a summary description of its primary facilities. Site operations, including special nuclear materials (SNM) management, waste management, deactivation, decontamination, and decommissioning (DD&D), environmental restoration, and Site support services are also discussed.

2.2 Site Overview

The Site, which is owned by the Federal Government, began operations in 1952 as the Rocky Flats Plant. Operated by what is now the U.S. Department of Energy (DOE), the Site's primary mission was production of component parts for nuclear weapons. Key activities at the Site included fabrication of parts from plutonium, uranium, and nonradioactive metals as well as recovery and recycling of plutonium and enriched uranium. In addition to production operations, plant operations included research and development, analytical laboratory functions, and storage, treatment, and transport of waste.

Plutonium manufacturing activities were suspended in 1989. The plutonium manufacturing mission was discontinued in 1992, and by September 30, 1994, the transition from a nuclear weapons defense mission to a materials and waste management and environmental restoration mission was complete. Landlord responsibility for most of the Site was transferred on September 15, 1993, from DOE's Office of Defense Programs to the Office of Environmental Restoration and Waste Management. Kaiser-Hill Company, L.L.C., in July 1995, became the Site contractor responsible for program planning and implementation. As of December 1996, approximately 6,500 people, including DOE, contractor, and subcontractor personnel, were employed at the Site.

2.2.1 Location and Setting

The Site occupies 6,262 acres in Jefferson County, Colorado, approximately 16 miles northwest of downtown Denver. The Site is situated at an elevation of approximately 6,000 feet and is less than 2 miles east of the Front Range of the Rocky Mountains and 16 miles east of the Continental Divide. The Site is surrounded by the communities of Superior, Boulder, Broomfield, Westminster, Arvada, and Golden. A map showing the Site's location and proximity to these communities is provided in Figure 2-1.

State Highway 128 borders the Site on the north. Most of the land directly north of this highway is designated as open space. Land directly south of the Site is used for grazing and hay production and is zoned agricultural/commercial. Indiana Avenue borders the Site on the east. The northern portion of land east of Indiana Avenue is zoned industrial/commercial and is privately owned with no existing development. Further south along Indiana Avenue, the land is owned by the City of Broomfield and is zoned as open space. Great Western Reservoir, a municipal water supply, is located in this section of land. The remaining portion of land bordering the Site on the east is zoned agricultural, with a projected plan showing an open space designation. State Highway 93 borders the Site on the west. Land to the west and southwest of the Site is used for quarrying (primarily clay, sand, and gravel) and storage and conveyance of municipal water supplies. The land is zoned agricultural/industrial but has a future commercial/office/ industrial designation. Land directly west of the Site is zoned agricultural, with plans showing industrial and office designations.

Water flows from west to east across the Site through three primary drainages: Rock Creek, Walnut Creek, and Woman Creek. Historically, the manufacturing, processing, and waste handling and storage activities—and therefore potential contaminant source areas—have been restricted to areas within the boundaries of the Walnut Creek and Woman Creek drainages. Water in Walnut Creek and Woman Creek flows toward two reservoirs used for municipal water supply—Great Western Reservoir and Standley Lake. The potential for municipal water supply contamination has been addressed by several recent projects. In 1989 Walnut Creek drainage was diverted around Great Western Reservoir to the South Platte River and by late 1997 a DOE funded project to substitute the City of Broomfield's water supply previously taken from Great Western Reservoir will be complete. The potential contamination of Standley Lake was addressed in a recently completed (late 1995) Standley Lake Protection Project, which included the construction of a holding reservoir able to contain the run-off from a 100 year storm event.

2.2.2 Site Facilities

The Site consists of a 384-acre Industrial Area surrounded by a 5,878-acre Buffer Zone. The Industrial Area, which contains most of the Site's primary facilities, is divided by Central Avenue running east to west. The area north of Central Avenue contains facilities related to plutonium operations, and the area south of Central Avenue contains non-plutonium handling facilities (primarily for uranium and stainless steel), former manufacturing facilities, and general plant support facilities. To meet safeguards and security requirements, an extensive security fence system surrounds all plutonium handling and storage buildings within the Industrial Area; this fenced area is called the Protected Area. A map showing the Industrial Area, the Buffer Zone, and the Protected Area is provided in Figure 2-2.

A detailed map of the Industrial Area is provided in Figure 2-3; key facilities are highlighted in green. Key facilities and structures at the Site are listed in Table 2-1.

Table 2-1. Key Facilities and Structures at the Site

Building Number	Description
123	Health physics: medical center: laboratory for analyses of worker health and exposure
130	Office space; warehouse
B130	Office space
334	General maintenance
335	Fire training
371/374	SNM storage (stacker/retriever): drum storage and associated inventory functions: liquid waste treatment; analytical and standards laboratory
440	Former non-plutonium manufacturing: future waste storage
444	Testing and calibration support: former fabrication of depleted uranium and beryllium parts: metal foundry and machining
460	Former fabrication, assembly, and testing of non-nuclear components: testing and calibration support: support for nondestructive assay: current office space for DOE federal staff
559	Laboratory for plutonium analyses
664	Waste storage and shipping (prepackaged hazardous, low-level mixed, and transuranic (TRU)-mixed waste and mixed residues)
707	Designed for plutonium fabrication, storage, and component assembly operations: current mission is thermal stabilization of plutonium oxides and repackaging of plutonium metal and oxide, temporary storage of radioactive materials from other facilities, treatment of certain residues
750	Production engineering support; office space
771	Designed for recovery and refining of plutonium metal and americium oxides; current mission is liquid waste treatment and temporary storage of nuclear materials
774	Low-level waste treatment: site-wide waste operations support: liquid waste solidification
776/777	Former nuclear operations facility; current mission is TRU waste treatment and temporary storage of nuclear materials
779	Former R&D facility now in deactivation
865	Maintenance and support facility; metallurgical laboratory
881	Central computer facility; research and engineering laboratory (non-plutonium); administrative support
883	Former uranium parts fabrication: waste tank storage
886	Former mission was criticality mass measurement experiments: facility being deactivated
889	Equipment decontamination: waste reduction of equipment and waste outside the Protected Area
891	Treatment facility for 881 Hillside ground water treatment project
903 Pad	Asphalt-capped, plutonium-contaminated soils
904 Tents	Temporary storage for two low-level waste forms (pondcrete, saltcrete)
991	Warehouse for testing/inspecting vendor items; nondestructive testing: metallography
Present Landfill	Operational sanitary landfill (scheduled to close when new landfill opens)
New Landfill	Under construction for disposal of sanitary waste; scheduled to open in April 1997
Firing Range	Used by protective force for training, qualification, and drills
Decontamination Pads	Outdoor facilities for decontamination of heavy equipment and drums
Property Utilization and Disposal Yards	Yards for screening materials for radiological/chemical contamination and evaluation for recycling or removal off-site: storage areas for excess, scrap, and bulk materials pending disposition

2.3 Site Operations

Although the Site's mission has changed from production to cleanup, a number of Site operations continue because they are necessary for implementing the programs required to fulfill the new Site mission. These operations are conducted under five primary program areas:

1. SNM Management, which includes special handling (e.g., storage, stabilization, repackaging, processing) of SNM with respect to safeguards and security and protection of human health and the environment
2. Facility Disposition, including all DD&D activities necessary to remove radioactive and hazardous sources from surplus buildings, equipment, systems, and other ancillary structures at the Site; decommissioning may also involve the dismantling and demolition of facilities
3. Waste Management, which provides for minimization, characterization, treatment, storage, and disposal of waste generated from past and ongoing Site activities
4. Environmental Restoration, which provides for assessment and remediation of contamination resulting from past plant operations, including Site contaminant identification and characterization, remedial design and cleanup actions, and post-closure monitoring and inspection activities
5. Site Support Services, which includes a wide range of operations (such as emergency response, building and road maintenance, real property management, and site-wide monitoring) necessary for maintaining safety systems and supporting the other program areas

These programs are highly interdependent. For example, the amount of waste generated by activities conducted under the SNM Management, DD&D, and Environmental Restoration program areas determines the scope of the Waste Management program. Similarly, the level of Site Support Services required depends on the level of activities conducted under the other program areas.

The five primary Site program areas and the activities conducted under each are described below.

2.3.1 Special Nuclear Materials Management

SNM consists of materials, as defined in the Atomic Energy Act of 1954, with the capability of undergoing fission (the splitting of the atomic nucleus by slow neutrons). These materials require special handling with respect to safeguards and security and protection of human health and the environment. SNM includes:

- All isotopes of plutonium,
- Uranium enriched with more than a natural abundance (0.7%) of fissile isotopes, including uranium-233, uranium-234, and uranium-235,
- Highly enriched uranium (HEU) (with concentrations of uranium-235 greater than 20%) or other fissile isotopes (americium-241 and neptunium-237).

SNM at the Site consists predominantly of plutonium-239 and enriched uranium. The majority of SNM occurs in three different forms of plutonium:

- Metal-pieces of SNM weighing 50 grams or more, plutonium metal generally consisting of raw materials (buttons and ingots) and semi-fabricated or completed weapons components,
- Oxide-pure plutonium oxide, plutonium oxide mixtures, plutonium/enriched uranium mixtures, and metal pieces weighing less than 50 grams, some plutonium oxides are

by-products of weapons fabrication and plutonium processing activities and may contain impurities such as fluorides and greases,

- Pits-nuclear weapons components, which were the main nuclear products formerly manufactured at the Site, pits are hollow metal spheres that are sealed to provide their own containment.

Some SNM is also present in transuranic (TRU) waste and liquid and solid residues, but because of the lower concentrations in these forms, the SNM is treated as waste. SNM is presumed to have a potential future use in the DOE system.

Consistent with DOE's openness initiative, Secretary of Energy Hazel O'Leary announced in 1993 that the total measured inventory of weapons-grade fissile material at the Site includes 12,900 kg of plutonium and 6,700 kg of enriched uranium (DOE 1996g). Table 2-2 provides an updated estimate of plutonium and enriched uranium inventory by building. The current inventory estimate, as of December 1996, reflects off-site shipments of plutonium and enriched uranium (e.g., pit shipments to Los Alamos National Laboratory/Lawrence Livermore National Laboratory, Building 886 Highly Enriched Uranyl Nitrate (HEUN) solution shipments to Nuclear Fuel Services, and HEU products shipped to Y-12).

Table 2-2. Unclassified Approximations of Plutonium and Enriched Uranium by Building

Building	Enriched Uranium (kg)	Plutonium (kg)					
		Metal and Oxide	Solid Residues	Liquid Residues	TRU Waste	Subtotal	Estimated Holdup
371/374	2,300	5,700	1,900	< 5	20	7,625	30
559		< 2				< 2	< 1
569					< 5	< 5	
664					< 10	< 10	
707	450	2,200	40			2,240	50
771/774	<10	400	300	100		800	100
776/777	2,700	1,300	700		< 10	2010	100
779		8				8	20
886	< 15					0	
991	800				< 5	< 5	
Total	**6,275**	**9,610**	**2,940**	**105**	**< 50**	**12,705**	**301**

Note: Cells with no entry may include a small amount of enriched uranium or plutonium in containers or holdup. SNM storage in Buildings 886 and 779 is being discontinued to support deactivation and decommissioning.

The distribution of plutonium and enriched uranium among buildings changes continuously as SNM consolidation into Building 371 progresses. As of December 1996, approximately 60% of the Site's SNM inventory had been consolidated into Building 371.

The SNM, residue, and TRU waste inventory is packaged in 1-gallon bottles for solution, and small "produce" cans, large cans, 10-gallon drums, 30-gallon drums, 55-gallon drums, and various other containers for solids. Several types of space within buildings are used for SNM storage, including vaults, rooms, gloveboxes, and tanks. Material forms, containers, and DOE complex-wide options for long-term storage have been evaluated in DOE's *Storage and Disposition of Weapons-Usable Fissile Materials PEIS* (DOE 1996b). Short-term or interim requirements for safe storage are being addressed by the Site.

Ongoing SNM management includes direct and support activities that ensure continued safe and secure storage of these materials and off-site shipment. Support activities include building and safety system maintenance and surveillance, SNM accountability (maintaining inventory records by location for all SNM), on-site transportation, and nondestructive testing and assay.

Because many SNM items were originally packaged for temporary storage (no longer than five years), numerous items require processing and repackaging. Safety concerns with respect to plutonium storage were identified in DOE's *Plutonium Working Group Report on Environmental, Safety and Health Vulnerabilities Associated with the Department's Plutonium Storage* (DOE 1994n) and by Defense Nuclear Facilities Safety Board Recommendation 94-1, *Plutonium Storage Safety at Major Department of Energy Facilities* (DNFSB 1994a). In response to these concerns, the direct activities of thermal stabilization, repackaging and consolidation activities are ongoing.

Thermal stabilization and consolidation activities were addressed with respect to NEPA requirements by two environmental assessments discussed below.

The intent of the *Environmental Assessment for the Consolidation and Interim Storage of Special Nuclear Materials at Rocky Flats Environmental Technology Site* (DOE 1995l) was to describe the impacts of mitigating some of the vulnerabilities identified with respect to plutonium storage by consolidating SNM in Building 371. The primary advantage of relocating SNM to Building 371 is the building's seismic qualification, which is superior to that of other buildings available for SNM storage. In addition, as a part of the Site's response to Defense Nuclear Facility Safety Board Recommendation 94-3 (DNFSB 1994b), upgrades to increase Building 371's seismic capacity is being pursued. Consolidation of SNM into Building 371 will have the additional benefit of reducing costs related to building operation and protective force services. Treatment and repackaging of SNM are key components of this activity and will take several years to complete. Treatment typically involves thermal stabilization of material in oxide form to produce a form that is less susceptible to further oxidation and associated packaging decay.

Consolidation of SNM into Building 371 was approximately 60% complete as of December 1996. The majority of SNM has been removed from Buildings 779, 886 and 991.

Thermal stabilization has been used historically to render pyrophoric (spontaneously igniting) plutonium into a nonpyrophoric form. The process involves heating pyrophoric plutonium in a glovebox furnace under controlled conditions. Since production operations were suspended in 1989, a backlog of pyrophoric plutonium has accumulated. In accordance with the *Environmental Assessment for Resumption of Thermal Stabilization of Plutonium Oxide in Building 707,* thermal stabilization activities have resumed in Building 707, and additional stabilization capabilities are being developed. As of January 9, 1997, all backlog plutonium oxide had been brushed, stabilized and repackaged resulting in an additional 156 kg of oxide inventory. In addition, all items of plutonium metal that was in contact or in the proximity of plastics have been repackaged. Therefore, both plutonium metal and oxide is now in compliance with Site safety requirements (HSP 31.11) for storage, and future SNM material management will continue to ensure compliance with HSP 31.11 (Kaiser-Hill 1996b).

DOE has decided to move non-pit weapons useable plutonium metals and oxides to the Savannah River Site if a subsequent decision is made to immobilize plutonium at that site (See 62 Federal Register 3014 (Jan. 21, 1997)). The Department has recently announced its intent to prepare an environmental impact statement to consider among other things, the location of plutonium immobilization facilities. (See 62 Federal Register 28009 (May 22, 1997)). In that announcement, the Department indicated that its preferred alternative is to immobilize plutonium at the Savannah River Site (including non-pit weapons-usable plutonium from the RFETS).

2.3.2 Facility Disposition

Facility disposition is defined as the sequence of activities required to take a building, facility, or structure from its existing condition to final disposition. Buildings at Rocky Flats will be demolished during closure, unless identified for reuse. At the present time nine buildings, mostly office buildings, have been identified for reuse each building at Rocky Flats will be dispositioned. The overall approach, in order, will be:

- Remove all Strategic Nuclear Materials
- Remove all classified equipment, including documentation for its use
- Remove all useable equipment
- Perform a reconnaissance level characterization to define the type of contamination or safety hazard present
- Remove all containerized waste or valuable material
- Drain liquid waste and processing systems
- Close all RCRA units (or integrate a closure plan into the building disposition plan)
- Remove all transuranic waste (defined as materials with activities in excess of 100 nanocuries per gram)
- Strip out equipment, piping, ducts, glove boxes, and major electrical components
- Remove radioactive hot spots

As waste is generated in this sequence, it will be segregated by type: radioactive, mixed, hazardous, or sanitary. If prompt disposal of the waste is planned, the waste will be packaged to meet the waste acceptance criteria of the off-site disposal facility. Otherwise, it will be packaged for storage on site until a disposal site is identified. Determination of whether a generated waste is transuranic will be made by assaying the container after packaging and establishing its activity on a weight basis. The determination for low level waste will be made based on the presence of radiation in the material before its removal. Attention will be given to waste minimization, with effort being made to segregate radioactive contamination and remove it from the bulk material.

The building disposition process is defined in the Decommissioning Program Plan. As major risk reduction activities are completed the building enters the decommissioning process. When activities such as packaging and shipping plutonium or enriched uranium and processing of residues into shippable waste forms, are complete, the building will no longer be needed for SNM management or waste treatment. The building's function in the closure sequence will be completed and it will be decommissioned.

The rationale underlying the Decommissioning Program Plan is that most buildings at Rocky Flats can be decontaminated using known, demonstrated decommissioning techniques. For instance, many buildings at Rocky Flats were built between 1953 and 1980. Asbestos was often used as a construction or insulation material, and lead paint use was prevalent. PCBs and mercury were used in lighting systems. The techniques for removal of these contaminants are well known and routinely used. Likewise, removal of surficial radioactive materials is routinely done with protection of workers and control of effluent streams managed well by professionals skilled in this work. Personal protection and containment are often used.

The Decommissioning Program Plan (DPP), currently in draft, lays out a process based on identifying the contamination or physical hazard present, then planning the activities necessary to remove the contamination. Once the contaminants are dealt with, the building can be demolished or reused.

The facilities in which plutonium was processed and the laboratories that supported the processing are expected to demonstrate significant radioactive, and perhaps mixed contamination. The DPP calls for building specific decontamination plans for these facilities so that the detailed planning necessary for assuring containment of emissions and effluents is maintained, and the termed Decommissioning Operations Plans, are 371/374, 559, 707, 771/774, 776/777, 779, and 886.

The process established in the DPP encompasses remediation. For buildings identified as (or overlying) an Individual Hazardous Substance Site, or an identified Area of Concern, the remediation of the contaminated media will be planned and conducted under the familiar environmental restoration process. However, it is important to note that the characterization of contamination underlying or contiguous to a building will be a part of the overall characterization activities, and not an activity conducted after the building demolition is complete. It is through this process that closure of RCRA units can be most efficiently done, in some cases, by planning their closure as part of the remediation effort, after the above ground structure has been removed. In cases where Under Building Contamination is expected, its characterization and remediation, if found to be necessary, will be part of the planning for the building disposition. Since 1995, Rocky Flats has completed a number of deactivation, decontamination, and demolition activities:

Fiscal Year 1995

- Removal of three plastic tanks used for storage of sodium hydroxide solution
- Removal of a small security incinerator, including its transite enclosure
- Demolition of the East and West Industrial Area Guard Stations

Fiscal Year 1996

- Removal of Building 889, a cinder block and steel sided building with some uranium contamination in the floors and sumps
- Demolition of the two 400 Area Guard Posts
- Removal of the Central Avenue Electric Power Substation
- Demolition of Tanks 221 and 224, with recycling of 540,000 gallons of fuel. These were the backup bulk fuel storage for the central steam plant. Tank 221 was an 800,000 gallon tank and Tank 224 held 1,900,000 gallons
- Removal of nitric acid storage tanks 218-001 and 218-002
- Establishment of a centralized location for investigation and survey of potentially contaminated items from decontamination and decommissioning activities, this reduced waste generation, since only contaminated portions of equipment were disposed, and waste segregation was be accomplished

Fiscal Year 1997 through December 1996

- Decontamination of Buildings 883 and 865, where major beryllium and uranium-based radioactive contamination has been removed from equipment and radiation control areas
- Removal and shipment for reuse of 2,700 liters of enriched uranium solutions from Building 886
- Removal of all Special Nuclear Materials from Building 779, except in holdup areas

Closure of the Material Access Area in 779, including 3 RCRA units, and removal of all stored drums.

2.3.3 Waste Management

Waste management activities constitute many of the daily operations conducted at the Site. Waste is generated during routine operations including SNM repackaging, residue stabilization, RCRA closures, environmental restoration, and DD&D. Management of this waste will continue to be important as the Site proceeds with cleanup during the next 10 years. Routine operations include routine maintenance, surveys, and inspections; incidental construction; waste operations; laboratory activities; technology development activities; and safeguards management, as appropriate.

Waste management activities are conducted within the guidelines of the following regulatory drivers:

- Atomic Energy Act
- Colorado Hazardous Waste Act (CHWA) Resource Conservation and Recovery Act (RCRA)
- Toxic Substances Control Act (TSCA)
- Federal Facility Compliance Act (FFCA)
- Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)
- Rocky Flats Cleanup Agreement (RFCA)
- Administrative and judicial orders governing mixed residues

The 1996 inventory and projected generation rate for the numerous waste types at the Site are listed in Table 2-3. Each of these waste types and the activities for managing them are discussed below.

Table 2-3. Waste Inventory and Generation Rate for 1996

Description	Solid Res. (kg)	Liquid Res. (lt)	TRU	TRU-Mixed	Low-Level	Low-Level Mixed	Haz	TSCA	Medical	Sanitary (Solid)
Inventory	106,000 kg / 833m^3	26,250	710	560	6,500	16,700	270	20	–	–
Generator										
Routine Operations	–	–	9	9	670	180	70	–	5	10,300
Environmental Restoration	–	–	–	–	–	-	-	-	–	–
DD&D	–	–	6	6	930	120	10	–	–	1,900
Residue Stabilization	665	–	12	13	-	-	–	–	–	–
Total	665	–	**27**	**28**	**1,600**	**300**	**80**	-	5	**12,200**

Note: Volumes are in cubic meters except where noted.

Residues

Residues are by-products from processing that contain plutonium in sufficient quantities to have warranted (at the time of processing) recovery of nuclear material. In the past, the level that warranted recovery was based on the economic value of plutonium. An excess of weapons-grade plutonium now exists in the DOE system; therefore, plutonium will no longer be recovered for reuse from residues. Residues, which will undergo characterization, stabilization and repackaging and will either become plutonium oxide or be categorized as waste, must be managed to ensure safety with respect to human health and the environment.

For processing purposes, residues are divided into two groups; solid residues and liquid residues. Stabilization plans for both groups are described in the Defense Nuclear Facility Safety Board Recommendation 94-1, Plutonium Storage Safety at Major Department of Energy Facilities. This recommendation prescribes a three-year timeframe, starting May 1994, for processing high hazard residues and calls for all material to meet long-term storage standards within eight years. For liquid residues, there are no storage standards, as long-term storage of liquids is not considered viable. For solid residues, however, long-term storage standards are described in the Interim Safer Storage Criteria (ISSC). Liquid residues are being processed into plutonium oxide. Solid residues will be processed into plutonium oxide or will be immobilized or otherwise processed to facilitate disposal at the Waste Isolation Pilot Plant (WIPP). Any recovered plutonium oxide from solid and liquid residues will be stored as prescribed in per the long-term metal and oxide storage standard (DOE-STD-3013).

Mixed residues are subject to specific administrative and judicial orders. The principal legal obligations governing the management of solid mixed residues at the Site is the Settlement Agreement and Compliance Order on Consent No. 93-04-23-01 (Residue Order), which is overseen by the Colorado Department of Public Health and Environment (CDPHE), and the Rocky Flats Cleanup Agreement (RFCA), which is overseen by the EPA and CDPHE. The Residue Order requires implementation of the Mixed Residue Reduction Program, which in turn requires that mixed residues be processed into a form suitable for off-site disposal. Disposal would occur as expeditiously as possible and consistent with applicable RFCA milestones, once a disposal facility becomes available.

For liquid residues, the Residue Order also requires implementation of the Mixed Residue Tank Systems Management Plan. The plan includes two programs: the Mixed Residue Tank Closure Program and the Liquid Stabilization Program. The Mixed Residue Tank Closure Program covers decontamination and decommissioning of tanks and piping after the liquid residues are removed. Ongoing activities prior to the removal of residues from the Site are designed to provide for 1) safe storage, 2) processing and packaging to meet repository standards such as those for the Waste Isolation Pilot Plant, 3) regulatory compliance with RCRA, 4) meeting RFCA agreements, and 5) administrative and judicial orders governing mixed residues.

The solid residues comprise a variety of materials including salts, combustibles, filters, crucibles, graphite, gloves, sludges, incinerator ash, metal, glass, and resins. The inventory of solid residues at the Site is 106,000 kg or 833 cubic meters. Of this total 404 cubic meters are mixed residues (residues that contain RCRA-regulated constituents). Solid residues consist of 99 item description codes (IDCs). The plutonium content of the solid residues has an average plutonium concentration of about 3% and ranges from about 0.1% to 80%. The solid residues are stored in 4,000 10- and 55-gal drums and 4,000 other smaller containers. Residues are stored in rooms and vaults in Buildings 371, 707, 771, 776, and 777.

The continued storage of solid materials without stabilization poses numerous hazards. The specific hazard varies with the material type, storage age, and packaging configuration. Hazards from these residues include flammable gas generation and subsequent container pressurization, exothermic chemical reactions, container corrosion, radiolytic decomposition of plastics, shock sensitivity, pyrophoricity, and dispersibility.

As of December 1996, all solid residue drums with suspected hydrogen build-up have been vented and their vents outfitted with carbon filters. Some solid residues have been recharacterized. All resin drums, including backlog, have been sorted and cementation has been initiated. The majority of leaded gloves have been washed and repacked, and all solid residues have been placed into RCRA permitted areas.

In order to meet the RFETS cleanup and closure mission, residues will be removed from the Site.

Approximately 28,900 liters of actinide bearing, aqueous solutions, containing plutonium and uranium, remained in inventory after the 1989 curtailment. Actinide solutions were stored in 4 liter plastic bottles, tanks, and piping in Buildings 371, 559, 776/777, 779 and 771. Most of the liquid inventory is in Building 371 but most of the plutonium content is in Building 771. The tanks range in size from a few liters to thousands of liters. As of December 1996, __ liters of plutonium and uranium solutions have been stabilized, leaving 26,500 liters to stabilize.

The presence of solutions in tanking and piping in Building 771 creates an increasing safety risk due to the age and condition of the process equipment. Leaks are experienced routinely and are expected to increase with time. Equipment in Building 371 is in better condition and the frequency of leaks is significantly lower. Actinide solutions in tank systems also generate hydrogen through radiolytic decomposition of the solutions. Storage of actinide solutions in plastic bottles also presents a potential for leaks to occur from the embrittlement and pressurization of the plastic bottles through radiolytic attack.

The Liquid Stabilization Program involves draining and treating all solutions remaining in tanks, piping systems, or plastic bottles. The purpose of stabilization is to eliminate the immediate risk of radioactive contamination resulting from spills or leaks from deteriorating equipment or containers. In Building 771, plutonium is precipitated out of solutions as impure oxides, then stabilized, repackaged, stored in Building 774, and are destined to be sent to WIPP. Building 371 actinide solutions are processed through the Caustic Waste Treatment System. All oxides from the process will be stabilized and repackaged in the plutonium metal and oxide containers (DOE-STD-3013).

As of December 1996, 18 of the 23 process system tanks in Building 771 had been drained, which represents a significant percentage of the inventory to be processed. Mitigation of hydrogen build-up in tanks in Building 771 is complete and mitigation has been initiated in Building 371. Liquid treatment activities received NEPA coverage with the Environmental Assessment, Actinide Solution Processing at the Rocky Flats Environmental Technology Site (DOE 1995k).

As of December 1996, all 2700 liters of Highly Enriched Uranium Nitrate (HEUN) solutions from Building 886 were drained, bottled and shipped off-site to Nuclear Fuels Services in Erwin, Tennessee. This equated to a reduction of 569 kg of highly enriched uranium from the Site's inventory. In addition, 800 kg of Low Enriched Uranium (<4.5%) was moved from Building 886 to Building 991 for future shipment. The only SNM left in Building 886 is holdup in pipes, tanks or ducts. The MAA is expected to be closed in early 1997.

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Chapter 3
CID CASES

3.1 Introduction

This chapter will describe in detail the key assumptions associated with the *baseline* and *closure* cases. The key programs used to develop the *baseline* and *closure* cases are Special Nuclear Materials (SNM) management, Facility Disposition, Waste Management, Environmental Restoration, and Site Support Services. More information on these programs and the range of activities postulated for them under each case is provided below.

The *baseline* case was developed first. It represents a snapshot in time, reflecting the Site's activities along the five major programs as of December 1996. It sets the baseline against which the *closure* case can be evaluated and compared. The *closure* case was developed using the scope and key assumptions described in Reference Case 2 of the Site's draft Site Closure Plan dated February 1997.

The Site is also planning to Reference Case 5 of the draft Site Closure Plan. This case differs from Case 2 in that the first 3 years have a more aggressive funding profile (Additional $50 million in funding). This affects the risk profiles depicted in this CID in the following ways;

- Accelerated stabilization of high risk plutonium liquids, metals, oxides, and residues to enable SNM shipment off-site by 2004 (i.e. no Interim Storage Vault needed).
- End state achieved by end of fiscal year 2009 versus 2014.

3.2 Description of the *Baseline* and *Closure* Cases

Two cases are analyzed in this CID document in order to calculate the cumulative impacts to the worker, public and environment relative to the Site's activities over the draft Site Closure Plan timeframe. Table 3-1 provides specific details on project information for each of the major programs for the *baseline* and *closure* cases and is the basis for the impacts assessments in Chapter 5.

Following is a description of the major activities expected to occur under each case (broken down by the five major programs).

3.2.1 *BASELINE* CASE

SNM Management

SNM management includes continued consolidation of materials into Building 371 with 60% completed as of December 1996. All backlog plutonium (Pu) metal and oxide has been thermally stabilized and repackaged and is in compliance with HSP 31.11. Some plutonium pits have been shipped to Pantex and Los Alamos National Laboratory (LANL)/Lawrence Livermore National Laboratory (LLNL). Some Building 371 seismic upgrades were completed (T-line) in accordance with Defense Nuclear Facility Safety Board (DNFSB) Recommendation 94-3 Implementation Plan. Repackaging and shipments of enriched uranium to Oak Ridge are ongoing.

> *BASELINE* CASE
>
> - Baseline updated to reflect 1996 Site conditions for comparison and reflect current mission
> - SNM consolidation in B371 60% complete, stabilization and repackaging of Pu metal and oxides
> - Some treatment of solid residues; continue storage in existing facilities; continued stabilization of liquid residues
> - Minor DD&D activities (11 of 700 + facilities completed)
> - Store waste in existing on-site facilities. Minimal waste treatment. Off-site disposal where receptor site exists. Otherwise interim storage total waste inventory is 25,300 m^3 with minimal waste being generated
> - Site Support Services reflect 1996 levels. Total Site population around 6,500

Some solid residue treatment has occurred with focus on RCRA compliance and stabilizing high hazard residues (drum venting, installing carbon filters, recharacterization, stabilizing resin columns and repackaging leaded gloves). Residues continue to be stored in existing on-site facilities. As of December 1996, over 5,000 liters of liquid residues have been processed and 2,700 liters of HEUN has been shipped off-site.

Facility Disposition

Deactivation, decontamination and decommissioning (DD&D) of Building 889, oil tanks 221 and 224 and acid tanks 218-001 and 218-002 was completed. Deactivation of Buildings 779 and 886 will continue until all SNM (except holdup) and the majority of excess chemicals have been removed. The tanks and security incinerator were removed from Buildings 123 and 121, respectively. Seventy-three underground wells were abandoned. Six IHSS Underground Storage Tanks (USTs) and 10 single shelled USTs were remediated and closed. Eleven of over 700 facilities have completed DD&D.

Waste Management

Waste generation, treatment and disposal has been minimal for most types of waste. All waste storage continues to be in existing on-site facilities. Aqueous waste has been sampled, treated on-site and discharged. Sanitary wastes have been and will continue to be disposed on-site. The following reflect *baseline* activities:

- TRU/TRUM waste drums continue to be vented and head-space-gas analyses performed.
- Minimal treatment of LL/LLMW prior to shipment to Nevada Test Site (NTS) or private facilities like Envirocare in Utah for disposal where allowed.
- Organic liquids have been shipped to Oak Ridge for treatment and disposal.
- Some on-site reactive chemicals have been treated.
- Asbestos contaminated and hazardous waste have been shipped off-site for disposal.

- Contaminated Polychlorinated Biphenyls (PCB) waste continues to be stored on-site until an off-site disposal facility is identified.
- Sanitary waste has been disposed of on-site.

Environmental Restoration

As of December 1996, some IHSS remediation, solar ponds sludge removal, closure of USTs and CERCLA No Further Action determinations have occurred in the environmental restoration program. The following reflect *baseline* activities:

- Trench 2 (T-2 Ryan's Pit), T3 and T4 have been remediated to current soil action levels.
- Solar pond sludge was removed and stored in tanks for future treatment and disposal.
- Limited soil remediation has occurred at six locations within the 881 Hillside.
- Mound plume was collected, transported and treated in Building 891.
- Leachate from the active sanitary landfill was collected and treated.
- Interim closures of six IHSS USTs and ten single shelled USTs was completed.
- Groundwater monitoring, pond operations and surface water monitoring was continued.
- CERCLA No Further Action determinations were made for Walnut Creek Drainage, Off-site Releases, West Spray Fields and Inside Building Closures.

Site Support Services

Only high priority systems were maintained and repaired, and minimal maintenance of surface water structures occurred. Security, environmental monitoring, utilities and other infrastructure support is reflected at 1996 levels.

3.2.2 *CLOSURE* CASE

SNM Management

SNM management includes stabilizing and repackaging for long term storage (DOE-STD-3013), 6,600/3,200 kg plutonium metal/oxides in Building 707. Figure 3-1 identifies the timeline assuming one Pu Stabilization and Packaging System (SPS) line. The *closure* case assumes one SPS line will be installed. The CID analysis of the *Closure* case is based on the draft Site Closure Plan Case 2 which states that plutonium metals and oxides will be transferred from Building 371 by April 2003 into a newly constructed vault for interim storage until it can be shipped off-site by the end of 2013. The majority of plutonium pits would be repackaged in DOE Type B containers and shipped to Pantex. Some pits continue to be shipped to LANL and LLNL. Some upgrades and seismic reinforcements to Building 371 are performed in accordance with

CLOSURE CASE

- Repackage Pu metal and oxide into DOE-STD-3013 containers. Consolidate SNM in a newly constructed vault. Ship pits to Pantex.
- Process/stabilize solid residues to meet SISMP, Rev. 5.0 and Interim Safe Storage Criteria. Process/stabilize liquid residues by FY99.
- DD&D (including demolition) 700+ buildings on-site, except nine designated for reuse.
- Construct a new staging/shipping facility for TRU/TRUM waste; consolidate TRU/TRUM and LL/LLM waste into B440, 664, 991 and 906. Build on-site storage CAMU as a contingency for remediation waste. Minimal on-site treatment. Ship TRU/TRUM waste to WIPP. Ship LL/LLM waste to NTS, Envirocare or Hanford for treatment and/or disposal. Ship organic waste to Oak Ridge for treatment and disposal.
- Site support services commensurate with requirements of other programs, for the most part will be scaled down.

DNFSB Recommendation 94-3 Implementation Plan.

A total of 106,000 kg bulk solid residues equating to 3,100 kg of plutonium is processed, repackaged and placed in interim safe storage pending ultimate disposal at the Waste Isolation Pilot Plant (WIPP). Processing will begin in August 1997 and be complete in 2002. Approximately 26,250 liters of liquid residues are stabilized and processed. TRU and LLW are generated based on full-scale SNM activities. Enriched uranium metal are repackaged and shipped to Oak Ridge.

Facility Disposition

The Site's 700+ facilities and structures are deactivated and demolished. This includes nine plutonium production facilities with high levels of plutonium contamination and six uranium production facilities with high levels of uranium contamination. Numerous support buildings with known radiological contamination are also decommissioned. These buildings are currently used for waste storage, processing, and maintenance. The majority of buildings that will be demolished are not radiologically contaminated.

Most of the DD&D work takes place between 2006 to 2010. New facilities constructed to temporarily manage radioactive waste and plutonium may also be deactivated and demolished once the waste and plutonium are shipped off-site. Most of the facilities will be closed by 2014. Nine facilities designated for reuse may not be demolished. These are Buildings 130, 131, 125, 850, 444, 447, 865, 883 and 460.

Waste Management

Waste generation levels are very high because of the large increase in DD&D activities and residue processing. On-site treatment processes are minimized. All Site waste is consolidated into Buildings 440, 664, 991 and 906. A new staging/shipping facility for TRU/TRUM waste, and an on-site storage Corrective Action Management Unit (CAMU), as a contingency, for remediation waste are constructed. TRU/TRUM waste are shipped to WIPP for disposal starting fiscal year 1998 and ending fiscal year 2012. There may be some treatment of TRU/TRUM waste at Idaho National Environmental Engineering Laboratory (INEEL) prior to disposal at WIPP. LL/LLMW is shipped to NTS, Envirocare or Hanford for treatment and/or disposal. Organic waste is shipped to Oak Ridge for treatment and disposal. The following reflects *baseline* activities:

- Consolidate all on-site waste storage into Buildings 440, 664, 991 and 906.
- Build a new staging/shipping facility for TRU/TRUM waste in fiscal year 2000. Some treatment (approximately 35%) will occur at INEEL. Ship to WIPP for disposal from fiscal year 1998 to fiscal year 2012.
- Ship LLW to NTS for disposal. Treat and dispose pondcrete/saltcrete at Envirocare by fiscal year 2000. Ship other LLMW to either Envirocare or Hanford for treatment and disposal.
- Build on-site storage CAMU for restoration waste as a contingency. Decision to build CAMU will be made in fiscal year 2002. Final disposal will be off-site.
- Treat liquid waste in Building 374 or in a new treatment facility. Ship organic liquid wastes to Oak Ridge for treatment and disposal.
- Some on-site treatment of reactive chemicals. Ship remaining reactive chemicals off-site for treatment, recycling, reclamation and disposal.

- Dispose radiological asbestos at Hanford. Dispose non-radiological asbestos to local waste broker. Ship PCB liquids to Oak Ridge Toxic Substance Control Act (TSCA) incinerator for treatment and disposal.
- Treat liquid sanitary waste at Sewage Treatment Plant (Building 995). Discharge treated liquid into ponds.
- Dispose of solid sanitary waste at an off-site commercial landfill.

Environmental Restoration

Approximately 6,100 acres of the Site support open space uses (5,000 acres unrestricted open space). Approximately 100 acres of the Site are occupied by man-made earthen covers placed over any areas of contamination that remain, such as old landfills. These 100 acres are restricted open space. Approximately 52 IHSSs are cleaned up to reduce or remove the sources of contamination. Continuous environmental monitoring is performed. The following reflects closure case activities:

- Ship solar pond sludge to off-site for treatment and disposal. Cap solar ponds.
- Continue 881 Hillside soil remediation. Remove french-drain system and recovery wells from operation.
- Contain, treat and discharge three groundwater plumes (903 Pad, Mound Area and East Trenches).
- Cap the present landfill and perform post-closure monitoring.
- Remediate and install cap over 300 and 700 areas to meet industrial land use standards.
- Excavate and treat, if necessary, prior to off-site disposal, contaminated media from high-risk IHSSs, under-buildings and potential areas of concern in the Industrial Area.
- Convert ponds to flow through system. Once DD&D and environmental restoration are completed, convert ponds to wetlands.

Site Support Services

The Protected Area will be progressively reduced, with a corresponding reduction in the protective force, once SNM is consolidated into Building 371, then further when SNM is moved to the Interim Storage Vault (ISV) and later off-site. Building maintenance and surveillance will be gradually reduced due to consolidation of SNM, waste and building DD&D. Utility systems use off-site supplies whenever possible. Most of the infrastructure support systems will be needed until fiscal year 2006. Surface water structures are maintained. Increase environmental monitoring for air, ground water, surface water, and the ecology during remediation and DD&D, then decrease as these activities are completed. Convert ponds from batch release to flow through and then to wetlands.

Table 3-1 Detailed Description of CID Cases

Baseline Case	*Closure Case*
Special Nuclear Material • As of December 1996 the Site is storing 6,600 kg Pu metal, 3,200 kg plutonium oxide, 3,100 kg Pu in residues and 6,700 kg enriched uranium. SNM will continue to be consolidated into Building 371. As of December 1996, 60% of the Pu metal and oxide has been consolidated into Building 371. • As of January 9, 1997, all backlog Pu oxide has been thermally stabilized & repackaged meeting HSP 31.11. All Pu in contact or in proximity with plastic has been repackaged. The Site dispositioned over 1,350 Pu metal items not in compliance with HSP 31.11 and generated 156 kg of Pu oxide which was thermally stabilized and repackaged. Compliance with HSP 31.11 will continue. • Pits will continue to be shipped off-site to Pantex, LANL, and LLNL per negotiated shipper/receiver agreements. • 6,700 kg enriched uranium will continue to be stored until shipment off-site.	**Special Nuclear Material** • All Site SNM consolidated into Building 371 by end of FY02. • All Site SNM transferred from Building 371 to the ISV by 4/03. • All Site SNM shipped off-site by end of FY13. • Pits will continue to be shipped off-site to Pantex, LANL, and LLNL per negotiated shipper/receiver agreements. • Pu metal and oxide will continue to be maintained in compliance with HSP 31.11. This may require additional brushing, thermal stabilization and repackaging activities in Building 707 Modules J and K until end of FY00. In addition, up to 1,500 kg of Pu oxide may arise from residue processing. • Pu metal too large to fit into 3013 containers will be size reduced in Building 707 module K starting 4/98 and completing end of FY00. • Pu metal and oxide will be repackaged to DOE-STD-3013 in Building 707, Module J starting 3/98 and ending 5/02.

Solid PU Residues Treatment
• Stabilized 665 kg of the 106,000 kg of backlog residues. This included 7 drums of resin and 11 drums of leaded gloves. In addition, all high hazard residue issues have been mitigated via drum venting reducing risks from hydrogen accumulation, sampling dozens of residue packages for verification of safety hazards, and continued frequent inspections.
	Solid PU Residues Treatment
	• Solid residues will be treated from 8/97 to 5/02 to meet ISSC and WIPP WAC in accordance with SISMP Rev. 5.0. Treatment is as follows:
	  • <u>Salts</u>: 16,000 kg bulk and 1,000 kg Pu residue salts (DOR, ER/MSE) will be processed in Building 707 module A to produce 8,000 drums of TRU waste. Processing includes unpacking, preparation of charge, pyro-oxidation, in-line repacking into pipe component and nondestructive assaying.
	  • <u>Ash</u>: 23,987 kg bulk, 1,186 kg Pu residue ash (sand, slag & crucible, graphite fines and incinerator ash) will be processed in Building 707 modules E and F to produce 10,100 drums of TRU waste. Unpacked in F and sent to E to be batched, calcined, repackaged into pipe component and nondestructive assayed.
	  • <u>Dry Combustibles</u>: 6,590 kg bulk, 30 kg Pu dry combustibles and several other residues not requiring chemical stabilization will be repacked and processed in Building 707 Module D to produce 1,900 drums of TRU waste. This includes unpacking, size reduction (shredding), batching, repacking and nondestructive assay.
	  • <u>Wet Combustibles</u>: 11,440 kg bulk, 207 kg Pu wet combustibles will be processed in Building 371 to produce 13,000 drums of TRU waste.
	  • Sorting, shredding, aqueous washing, drying, repacking and nondestructive assay. Organic material will undergo low temperature desorption. Fluorides will undergo dissolution, precipitation and calcination.
	  • <u>Inorganics / Miscellaneous:</u> (includes sludges, grease, and non-fine graphite) 48,050 kg bulk, 516 kg Pu. Sorting, repacking, drying and nondestructive assay.

Baseline Case	*Closure Case*
Solid PU Residues Storage • Residue drums and containers continue to be stored in existing areas in Buildings 371, 374, 707, 771, 774 and 776/777.	**Solid PU Residues Storage** • Once residues are treated they will be stored in Building 371 and TRU waste buildings outside of the PA until shipment to WIPP as TRU/TRUM waste.
Solid PU Residues Disposal • No disposal site currently exists.	**Solid PU Residues Disposal** • Ship 100% of solid residues to WIPP beginning FY98 and ending 2006.
Residue Liquids • Continue stabilization of 26,250 liters of backlog liquid mixed residues. This involves liquid removal from tanks, piping and other containers stored in Buildings 371, 771, 559 and 776/777; processing of the liquids to convert them to various forms for safe interim storage; mitigation of hydrogen in tanks; and mixed residue RCRA tank closure support. • As of December 1996, 2,700 liters (569 kg enriched uranium). HEUN solutions from Building 886 were shipped off-site. 18 of 23 process system tanks in Building 771 had been drained. Mitigation of hydrogen build-up in tanks in Building 771 is complete, and those in Building 371 have been started.	**Residue Liquids** • Drain 26,250 liters of liquids from rooms, tanks and piping systems. Process 300 liters through hydroxide precipitation and 780 liters through oxalate and 3,000 liters through bottle box in Building 771 and 25,250 liters through caustic waste treatment system in Building 371. • Assay 250 cans and 170 cans of Pu oxide and magnesium uranates, respectively. • Sample 84 tanks and piping systems for excess hydrogen gas. • Purge 28 tanks and piping systems of excess hydrogen gas. • Remove Raschig rings and sludge from 136 tanks in Buildings 771, 371, 776/777 and 707. • All liquid stabilization activities will be completed by FY99.
Waste Management • Storage on-site in existing facilities. Minimal on-site treatment. Disposal off-site where receptor site exists. Otherwise interim on-site storage of the current inventory 26,150 m^3 of total waste exists (as of December 1996). Of this 5% is uncontaminated/sanitary, 89% is LL/LLM, 5% is TRU/TRUM and 1% is hazardous waste. Refer to Table 2-4 for detailed breakout of waste volumes.	**Waste Management** • Consolidate storage on-site in Buildings 440, 664, 991 and 906. Treatment of mixed waste on and off-site, and disposal off-site. Approximately 325,000 m^3 of total waste will be dispositioned. 298,900 m^3 will be generated, 40% uncontaminated, 42% LL and LLM waste, 5% will be TRU and TRUM waste, 13% consisting of sanitary waste. Storage of LL/LLM waste in existing facilities and, if necessary, in a new Containerized Storage Facility. Includes storage of TRU/TRUM in existing facilities, and includes staging activities in the new TRU/TRUM staging and shipping facility. The following is the total volume of waste that will be managed over the life of the Site's closure.

Waste Type	Current Inventory (m^3)	Volume Generated (m^3)	Volume Treated (m^3)	Volume Disposed (m^3)
Uncontaminated	1,300	127,000	0	128,300
Sanitary Solids	0	41,000	0	41,000
Hazardous	250	2,100	2,350	2,350
LL - Process	6,600	17,900	0	24,500
LLM - Process	16,700	2,000	2,400	18,700
LL - Remediation	0	41,000	0	41,000
LLM - Remediation	0	54,400	27,200	54,400
TRU/TRUM	1,300	13,500	970	13,830*
Total	26,150	298,900	32,920	324,080

*Does not include volume treated.

Baseline Case	*Closure Case*
TRU and TRU-Mixed Waste • The 117 remaining unvented drums of TRU and TRUM waste will continue to be vented with carbon filters in early 1997. • A head-space-gas analysis will continue to be performed for approximately 200 drums of TRUM waste per year. • TRU waste would continue to be stored in existing storage areas. • No expansion of non-destructive assay, real-time radiography, repackaging, or characterization capacities would occur. • On-site interim storage would continue pending opening of WIPP.	**TRU and TRU-Mixed Waste** • Consolidate storage of TRU/TRUM into Buildings 440, 664, 991. TRU/TRUM will be generated from two primary sources: (1) residue stabilization and processing, and; (2) deactivation, decontamination and decommissioning. • Staging in Building 664 for shipment to WIPP. • Build new staging/shipping facility in FY00. Approximately 35% will require treatment at INEEL Advanced Mixed Waste Treatment Facility beginning in FY04. INEEL would complete shipment to WIPP. • Begin shipment to WIPP in FY98. Disposal will continue with the inventory completely dispositioned by the last year of generation (FY12).
Low-Level Remediation Waste Treatment • The Building 374 Liquid Waste Treatment Facility will be used. • Other backlog LLW (including sludges, combustibles, filters and media, glass, and metal) will not be treated. • A few LLW (classified waste, solid excess chemicals) will remain in storage until a treatment process is defined and implemented. • Newly generated LLW should not require treatment. • Stored in existing facilities awaiting off-site disposal at NTS. • No on-site treatment or disposal.	**Low-Level Remediation Waste Treatment** • Stored in existing facilities. Beginning in FY03, generation will increase dramatically as remediation efforts accelerate. Build contingent storage option, Containerized Storage Facility CAMU. Stored only long enough to facilitate shipment off-site for disposal. • No on-site treatment or disposal. • Dispose off-site at private facility like Envirocare in Utah and the NTS beginning in FY99. All LL Remediation waste will be dispositioned by the end of the last year of generation (FY12).
Low-Level Storage/Disposal • Low-level waste will continue to be stored in existing storage areas. • No expansion of non-destructive assay, real-time radiography, repackaging, or characterization capacities would occur. • Backlog LLW will be disposed at NTS.	**Low-Level Storage/Disposal** • Consolidate storage in Buildings 440, 664, and 906. Continue shipments to the NTS for disposal. • Shipment will not occur until FY01. • Treatment is not anticipated. • Process waste water will continue to be treated in the existing waste water treatment facility (Building 374) until the new Waste Water and Sludge Treatment Project is completed and placed into service. • All low-level process waste will be dispositioned by the end of the last year of generation (FY12).
Low-Level Mixed Waste Treatment • The Building 374 Liquid Waste Treatment Facility will be used. • Minimal treatment and in accordance with Site Treatment Plan. • Off-site treatment at Oak Ridge for organic liquids.	**Low-Level Mixed Waste Treatment** • 50% of the LLM remediation waste generated will require some form of additional treatment prior to ultimate off-site disposition. Use of on-site and/or off-site treatment is required. Treatment of the remaining inventory and future generation will occur on-site and/or off-site beginning in FY01. 50% will require some form of treatment prior to disposal. Preference will be given toward off-site treatment.

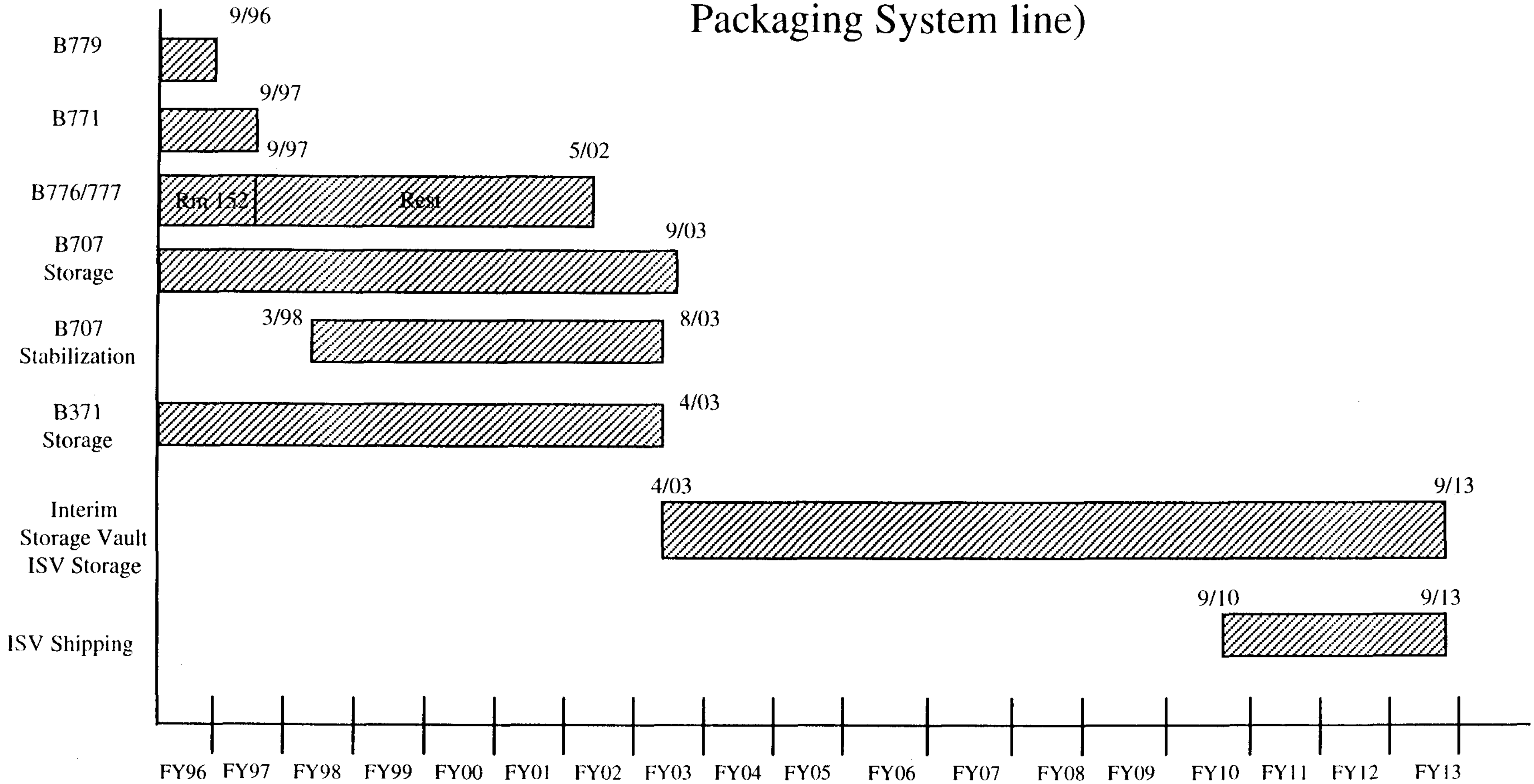
Baseline Case	Closure Case
Low-Level Mixed Waste Storage/Disposal • LLM waste will continue to be stored in existing storage areas, pending availability of off-site disposal. • No expansion of non-destructive assay, real-time radiography, repackaging, or characterization capacities will occur. • No disposal of LLM waste will occur, with the exception of backlog saltcrete in compliance with land disposal restrictions, and newly generated saltcrete, which will be disposed of at Envirocare (<5% of backlog).	**Low-Level Mixed Waste Storage/Disposal** • Consolidate storage in Buildings 440, 664, and 906. • Approximately 13,500m^3 of pondcrete and saltcrete will be treated and disposed at Envirocare by FY00. • Waste would be shipped for disposal, anticipated to be Hanford by FY01. All LLM process waste will be dispositioned by the end of the last year of generation (FY12).
Hazardous Waste Treatment • Reactive chemicals will be stabilized on-site using systems in Building 881 or bunkers.	**Hazardous Waste Treatment** • Reactive chemicals will be stabilized on-site using systems in Building 881 or bunkers.
Hazardous Waste Storage/Disposal • Storage of hazardous waste will be limited to short-term on-site storage awaiting shipment off-site. • Hazardous waste will be shipped off-site to a commercial facility for recycling, treatment, or disposal in the same year it is generated.	**Hazardous Waste Storage/Disposal** • Continue to be collected and staged in on-site storage facilities for shipment to off-site commercial facilities for treatment, recycle, reclamation and/or disposal. All hazardous waste will be dispositioned by the end of the last year of generation (FY12).
TSCA Waste (Rad/Nonrad) Treatment • No on-site treatment of TSCA waste will occur.	**TSCA Waste (Rad/Nonrad) Treatment** • No on-site treatment of TSCA waste will occur.
TSCA Waste (Rad/Nonrad) Storage/Disposal • On-site long-term storage of radiological PCBs will occur in Buildings 666 and 776. • Both radiological and nonradiological asbestos will be stored in Building 666 while awaiting shipment. • Radiological asbestos will be disposed of at the Hanford facility. • Nonradiological asbestos will be sent to a local waste broker for disposal. • Currently, radioactive PCB-contaminated TSCA waste does not have an identified disposal site.	**TSCA Waste (Rad/Nonrad) Storage/Disposal** • Both radiological and nonradiological asbestos will be stored in Building 666 while awaiting shipment. • Radiological asbestos will be disposed of at the Hanford facility. • Nonradiological asbestos will be sent to a local waste broker for disposal. • Radioactive PCB contaminated TSCA waste would be shipped to Oak Ridge TSCA incinerator for treatment and disposal.
Sanitary Waste Treatment • The sewage treatment plant would treat all liquid sanitary waste in the same year it was generated. Effluent would be limited to NPDES permit quantities and concentrations. • No treatment of solid sanitary waste will be required.	**Sanitary Waste Treatment** • The sewage treatment plant would treat all liquid sanitary waste in the same year it was generated. Effluent would be limited to NPDES permit quantities and concentrations. • No treatment of solid sanitary waste will be required.
Sanitary Waste Storage • No sanitary waste storage will [illegible] site.	**Sanitary Waste Storage** • No sanitary waste storage will occur on-site.
Sanitary Waste Tr[illegible]on and Disposal • Sanitary wa[illegible]posed of at the existing on-site landfill.	**Sanitary Waste Transportation and Disposal** • Collected and disposed in the on-site landfill (as they are today) or disposed off-site at a commercial landfill. Beginning in FY98, off-site commercial landfills will be utilized. All sanitary solids will be dispositioned by the end of the last year of generation (FY12).

Baseline Case	*Closure Case*
	Facility DD&D • Miscellaneous Production Zone Closure Project consists of 500 cluster (559, 566, 569) waste systems, storage calibration lab and infrastructure support. There are 30 IHSSs expected to have no further actions and 4 high risk IHSSs (Rad Site 559, under building contamination, 2 buildings, and Solar Ponds). Most of the D&D work will take place between FY07 to FY13. The project will be completed by FY13. • Building 991 Cluster Closure Project consists of Buildings 991, 985, 996-999, 989, 984 and 1 under building contamination high risk IHSS. Most of the work will be done between FY07 to FY08, and the project will be completed by FY08. • Building 779 Cluster Closure Project consists of Buildings 779, 2 plenum buildings, 9 support buildings, 6 storage tanks and 1 under building contamination high risk IHSS. Most of the work will be completed between FY97 to FY00. Deactivation will be done in FY97. D&D in FY98-FY99. Remediation of IHSS by FY00 and project closed by FY01. • Buffer Zone Closure Project consists of high risk IHSSs 170, 174.1 and 174.2, capping old sanitary landfill, D&D 130 cluster and turning ponds into wetlands. Most of the work will take place between FY04-FY06 and FY13-FY15. The project will be completed by FY15. Buildings 130 and 131 are designated for reuse.
Remedial Activities (General) • T2 (Ryan's Pit), T3 and T4 were remediated to current soil action levels.	**Remedial Activities (General)** • The Site will be remediated to open space land use standards for the Buffer Zone (5,875 acres) and industrial land use standards for the Industrial Area (130 acres). • Contaminated media from IHSSs, potential areas of concern, and under buildings will be excavated and treated, as necessary, prior to off-site disposal. • Remedial activities will be completed by FY14. • Surface water and ground water monitoring activities will increase during remediation and DD&D. Upon interim closure of the Site, monitoring activities will substantially decrease.
Solar Evaporation Ponds • Removed all pond sludge and stored in tanks for future treatment and disposal (747,000 gallons). • Collect contaminated ground water via Interceptor Trench System (ITS) and treat in Building 374.	**Solar Evaporation Ponds** • Approximately 7,448 cubic yards of pondcrete and 3,498 cubic yards of sludge are shipped off-site for treatment and disposal to approved disposal facilities. • Groundwater is collected and treated using passive systems and released. • Cap solar ponds, remove debris and dispose of sludge.
881 Hillside • Limited soil remediation at six locations within IHSS 119.1 and near 119.2. • Groundwater would be collected and treated under the existing Ground Water Interim Measure/Interim Remedial Action (891 Treatment Unit).	**881 Hillside** • Additional soil remediation within IHSS 119.1 occurs. This includes excavation, treatment and off-site disposal. • The Ground Water IM/IRA is discontinued. The current French-drain system and recovery wells are removed from operation.

Baseline Case	*Closure Case*
903 Pad, Mound Area, and East Trenches • T2 (Ryan's Pit), T3 & T4 have been remediated meeting current Soil Action Levels. • Mound plume being collected, transported and treated in Building 891.	**903 Pad, Mound Area, and East Trenches** • Contaminated soils and buried waste remaining in the area treated by low temperature thermal desorption, if necessary. • Stored on-site in contingency CAMU if necessary and off-site disposal. • Three groundwater plumes (Mound Plume, 903 Pad/Ryan's Pit Plume, East Trenches Plume) contained, treated and discharged.
Off-Site Releases, West Spray Field, Inside Building Closures • No further remediation would occur.	**Off-Site Releases, West Spray Field, Inside Building Closures** • No further remediation occurs.
Present Landfill • Used as active landfill. • Leachate collected and treated with granulated activated carbon treatment system and discharged.	**Present Landfill** • Implement EPA's presumptive remedy of capping the Present Landfill. The cap covers approximately 36 acres and requires approximately 243,500 cubic yards of cap material. • Post closure monitoring occurs.
Industrial Area (700 Area, Original Process Waste Lines, Other Outside Closures, 400/800 Area, 100 Area, 300 Area and Radioactive Sites, respectively) • Completed interim closure of 6 IHSS underground storage tanks and 10 single shelled USTs. • Surface water and ground water monitoring continues under the Industrial Area IM/IRA.	**Industrial Area (700 Area, Original Process Waste Lines, Other Outside Closures, 400/800 Area, 100 Area, 300 Area and Radioactive Sites, respectively)** • Approximately 327,000 cubic yards of clean fill and a layer of topsoil would be required to restore excavated areas to conditions capable of supporting native vegetation. • Consolidate contaminated soil and debris and install shallow fill cap over IHSS 115. • Excavate and treat, if necessary, contaminated media from high risk-ranked IHSSs, under-buildings, and potential areas of concern in the Industrial prior to off-site disposal. • Install engineered cap for 300 and 700 area of the Industrial Area after remediation (approximately 45 acres).
Old Sanitary Landfill • Continue ground water monitoring.	**Old Sanitary Landfill** • No remediation of the remaining IHSSs occurs, since contaminant concentrations are below standards.
Walnut Creek Drainage • No further remediation occurs. • Continue pond operations and surface water monitoring programs.	**Walnut Creek Drainage** • Continue operation of ponds and surface water monitoring programs. • Once DD&D and environmental restoration completed, convert ponds to wetlands (FY14).

Baseline Case	*Closure Case*
Site Support Operations • Continue security operations at FY96 levels. • Only continue maintenance and repairs of high priority building surveillance and safety systems.	**Site Support Operations** • Majority of site infrastructure support activities will be in operation until FY07: Process water operates until FY06 Sewage Treatment operates until FY06 Security operates until FY06 Steam Plant operates until FY07 Domestic Water operates until FY07 Fire Dept. operates until FY09 Groundwater Monitoring operates until FY10 Communications Systems operate until FY14 Roads/Fences operate until FY14 • Groundwater remediation system installed FY98. Surface water conversion to flow through system complete FY99 and to wetlands FY13. <u>Environmental Monitoring</u>: • Increase environmental monitoring from FY96 levels for air, ground water, surface water, and the ecology due to facility DD&D and environmental restoration activities, then decrease substantially as these activities end. <u>Utilities</u>: • Reconfigure utility systems for water (fire, drinking, process), electricity, natural gas, and communications to use off-site suppliers whenever possible. • Demand on utility systems and operations fluctuates. DD&D of facilities decreases the need for facility utilities.

Figure 3-1 Plutonium Metal & Oxide Consolidation and Stabilization Timeline (Assuming one Pu Stabilization and Packaging System line)



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CHAPTER 4
AFFECTED ENVIRONMENT

4.1 Introduction

This chapter describes baseline environmental resources and conditions at the Rocky Flats Environmental Technology Site (Site) and the activities required to operate the facility. The affected environment descriptions presented in this chapter provide the context for understanding the environmental consequences described in Chapter 5, "Environmental Consequences." As such, they serve as a baseline from which any environmental changes that may be brought about by implementation of the scenarios can be identified and evaluated. Potentially affected environmental resources and activities include:

- Geology
- Soils
- Water
- Air
- Traffic and Transportation
- Utilities
- Human Health and Safety
- Ecological Resources
- Cultural Resources
- Noise
- Socioeconomics
- Environmental Justice

During preparation of the Cumulative Impacts Document, the most up-to-date and accurate information available was used to describe the affected environment. Whenever possible, information from 1996 was used to assess baseline conditions; in cases where 1996 information was not available, other data were used. For example, because reliable surface water quality data were available from a 1992 characterization study, they were utilized as part of the description of baseline conditions. In all cases, use of data other than 1996 data is noted in the text. Relevant information of a highly detailed or technical nature is provided in the accompanying appendices.

Section headings for Chapters 4 and 5 ("Environmental Consequences") parallel one another whenever possible to allow for quick comparison of baseline conditions and potential environmental impacts.

4.2 Geology

This section describes the geological, mineral, and seismic characteristics of the Site and vicinity.

4.2.1 Site Geology

The Site is located on the flat-lying Rocky Flats pediment at an elevation of approximately 6,000 feet above mean sea level. The surface is broadly rolling and slopes gently to the east with a topographic relief of about 300 feet and a slope of approximately 1.5 degrees. Major stream valleys, which transect the pediment generally from west to east, originate in the mountains of the Front Range. Small tributaries to these major streams have developed locally. Moderately steep hillsides are commonly adjacent to the streams.

West of the Site, the Rocky Flats pediment terminates abruptly, giving way to the eastern margin of the Front Range, which is characterized by a narrow belt of ridges and upthrusts formed by steeply east-dipping sedimentary rock. East of the Site, the Rocky Flats pediment merges with the High Plains section of the Great Plains Province (Spencer 1961, Thornbury 1965, Hunt 1967).

Geologic units at the Site include unconsolidated surficial deposits and bedrock. Surficial deposits range in thickness from 0 to 100 feet and include artificial fill, colluvial (gravity), landslide, and alluvial (stream) deposits. The lateral distribution of these surficial units is illustrated in Figure 4.2-1. The characteristics of the surficial deposits are briefly described below and more thoroughly discussed in the *Geologic Characterization Report for the Rocky Flats Environmental Technology Site* (EG&G 1995f) and the *Preliminary Surficial Geologic Map of the Rocky Flats Plant and Vicinity* (USGS 1994).

The artificial fill deposits, present across the Site, include road and railroad embankments, earthen dams, and other engineered fills, as well as compacted and uncompacted landfills and spoil piles along some of the irrigation ditches. The artificial fill deposits are commonly less than 9 feet thick, although some of the earthen dams and landfills are greater than 30 feet thick (USGS 1994).

Colluvial deposits (rock detritus and soil accumulated at the foot of a slope) cover the steep hillsides in the incised stream drainages. These deposits were derived from older alluvial units and bedrock and were deposited by sheetwash and soil creep. Colluvial materials range in thickness from 3 to 15 feet (USGS 1994).

Landslide deposits are present along the steep hillsides in the incised drainages (Hurr 1976). Steep slopes resulting from landslides are present in all of the drainages and are most numerous in the Rock Creek drainage. These deposits range in thickness from 10 to 90 feet (USGS 1994).

Alluvial deposits occur in flood plains, stream channels, and terraces along drainages across the Site. The most widespread alluvial deposit in the region is the Rocky Flats Alluvium, which was deposited after the uplift of the Rocky Mountains as an alluvial fan deposit and caps the Rocky Flats pediment at the Site. Valley-fill alluvium consists of stream deposits that occur in and adjacent to ephemeral streams at the Site.

The bedrock units beneath the surficial deposits at the Site include: the Arapahoe Formation, Laramie Formation, and Fox Hills Sandstone. A generalized stratigraphic column illustrating the relationships and ages of these bedrock units is included in Figure 4.2-2. The characteristics and distribution of the bedrock units are discussed in detail in the *Geologic Characterization Report* (EG&G 1995f).

From top to bottom, the bedrock units occur as follows. The Arapahoe Formation is a fluvial (river) deposit that ranges from 0 to 50 feet in thickness beneath the Site (EG&G 1992c). It is composed of sandstones, siltstones, and claystones. River channel deposits have been identified in the Arapahoe Formation. The Laramie Formation is 600 to 800 feet thick beneath the Site and includes silty to clayey sandstones, clayey siltstones, and claystones. The Laramie Formation was deposited in a deltaic setting. The Fox Hills Sandstone is 90 to 140 feet thick and was deposited in a beach setting. The Pierre Shale, underlying the Fox Hills Sandstone, is greater than 7,000 feet thick and consists of dark-gray shale with minor amounts of siltstone and sandstone. This unit was deposited in a marine setting.

The structural geology of the Site and surrounding area is complex. The tectonic framework is dominated by structural features that formed during the uplift of the Rocky Mountains approximately 65 million years ago. These features include north-northwest-trending mountain ranges that are bounded by low-angle thrust faults. The sediments underlying the Site are flat-lying, and sediments to the west are east-dipping to vertical due to uplift tectonics. Figure 4.2-3 presents a generalized geologic cross-section that illustrates the structural setting in the region.

4.2.2 Geologic Hazards

Geologic hazards associated with the Site and vicinity include landslide, subsidence (settling), and seismic hazards in addition to hazards associated with human activities. Landslides have been a common occurrence along the steep valley sideslopes formed by streams because of the high clay content of the bedrock units (Hurr 1976). This phenomenon is not considered dangerous because the landslides are typically minor and occur in undeveloped or inaccessible areas (DOE 1980).

Subsidence in the region was generally associated with mining activities and oil and gas production. The only subsidence hazard potential identified near the Site is associated with surficial and underground mines 1.5 miles to the west; however, subsidence associated with these mines is local in nature (Amuendo 1978). No cases of fluid-related subsidence associated with the removal of oil, gas, or ground water have been reported in the area. Because underground mining and oil and gas production have not been conducted beneath the Site, the on-site potential for subsidence is low.

Because the Site is located in an area of past seismic (earthquake-related) activity, potential seismic hazards are addressed. Some tectonic activity has occurred in the Denver area within the last 35 years, with the most recent notable earthquake occurring on December 25, 1994. The epicenter of this earthquake was approximately 25 miles south of Denver near Castle Rock, Colorado. The magnitude of this earthquake was 4.0 on the Richter Scale (Minsch 1995).

The only major historical earthquake in Colorado was in 1882 (D&M 1981). The epicenter of this earthquake is thought to have been along a fault zone in the Piceance Basin near Rifle, Colorado, approximately 150 miles west of Denver. The magnitude estimates for this event range from 5.0 to 6.7 on the Richter Scale and are based on damage reports and the estimated area over which the event was felt (D&M 1981).

Between 1962 and 1967, tremors were felt in Denver in the vicinity of the Rocky Mountain Arsenal. These events have been attributed to the pumping of fluid into a deep injection well at the Arsenal. The three largest Rocky Mountain Arsenal seismic events had magnitudes of 4.9, 5.2, and 5.3 on the Richter Scale (DOE 1980). The correlation between waste disposal practices at Rocky Mountain Arsenal and seismic events has been studied by numerous investigators (e.g., Healy 1968, Simon 1968, Evans 1970, Major 1981). Waste disposal operations at the Arsenal no longer involve use of the deep injection well.

Recent investigations of potential seismic hazards at the Site include the *Seismic Hazard Analysis* (EG&G 1994o) and the *Geologic Characterization Report* (EG&G 1995f). The *Seismic Hazard Analysis,* completed as part of the Site's Systematic Evaluation Program, provides the most comprehensive assessment of seismic hazards at the Site. Seismic sources, historical seismic action, ground motion attenuation, soil expansion, soil liquefaction potential, and geotechnical stability were evaluated to quantify the seismic hazards. However, the *Seismic Hazard Analysis* did not address the seismic stability of specific artificial structures at the Site.

As discussed in the *Geologic Characterization Report*, seven faults in shallow bedrock within the boundary of the Site were inferred from stratigraphic correlations. A map illustrating the approximate locations of the faults is included as Figure 4.2-4. One of the faults identified—a northeast-trending reverse fault that extends across the western part of the Industrial Area and the Landfill Pond (Fault 2, Figure 4.2-4)—is of interest because it appears to lie near Building 371 in the Protected Area of the Site. Borings near the fault trace have revealed approximately 25 to 50 feet of bedrock displacement. To evaluate the possibility of recent movement along the faults identified at the Site, visual comparisons of geology, topography, and inferred fault locations were made. Trenching activities confirmed there was no evidence of displacement in the overlying Quarternary deposits, and it was concluded that no geologically recent (i.e., less than 500,000 years ago) movement has occurred along these faults.

Human activities that could affect the geology of the Site are limited to construction of buildings, disposal or storage cells, roads, and canals; soil excavation and treatment; impoundment of small reservoirs; and excavation of gravel and clay pits. None of these activities is believed to represent a concern relative to adverse geologic impact. No hazard from the failure of reservoir impoundments in the area exists; reservoirs in the vicinity lie downstream of Site facilities, are too small to impact Site facilities, or are on drainages that would not affect Site facilities.

4.2.3 Mineral Resources

Mineral resources near the Site include uranium, crushed rock, oil, natural gas, coal, clay, sand, and gravel.

Uranium and crushed rock have been derived from metamorphic rocks in the area. The nearest uranium mine, the Schwartzwalder uranium mine, was located 4 miles southwest of the Site and was the largest vein-type uranium deposit mined in Colorado until its closure in 1986. As of 1980, ore shipments have yielded more than 11.5 million pounds of uranium oxide (U_3O_8). The Schwartzwalder mine closed in 1986 and is scheduled to reopen in late 1996 (Lando 1996). Crushed rock is still quarried in the area. The Ralston Quarry of the Asphalt Paving Company is located approximately 4 miles southwest of the Site. Neither of these resources is suitable for mining at the Site because the source rocks are at great depth beneath the ground surface.

Sedimentary rocks of the Denver region contain substantial reserves of hydrocarbons (Kirkham 1980, Sonnenberg 1981). Petroleum has been discovered within thin layers of the Pierre Shale and the Dakota Group (Weimer 1976). Other possible producing units beneath the Site include the Lyons Sandstone, Benton Shale, and Niobrara Formation (Van Horn 1976). The nearest oil field is a small field located north of Boulder (EG&G 1994g). No commercial accumulations of oil or natural gas have been identified in the area around the Site.

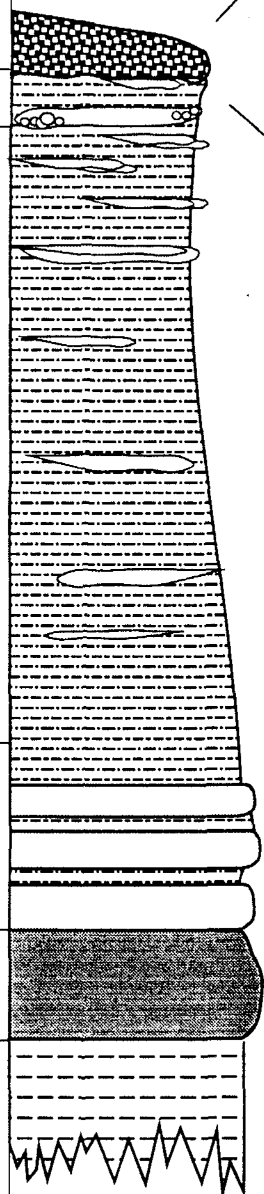
Coal has been mined in the area from the base of the Laramie Formation and upper portions of the Pierre Shale. Access to the thin coal seams is cumbersome, and it is postulated that few sizable coal deposits remain (EG&G 1994g). Coal was mined at the Caprock Mine outside the southwestern corner of the Site until 1953 (EG&G 1994g). An estimated 10 million tons of coal have been removed from 13 mines in the Golden area south of the Site. Clay sources include the base of the Laramie Formation southwest of the Site and the upper portions of the Pierre Shale to the northwest. Clays from the Pierre Shale are treated to form a lightweight aggregate at the Western Aggregates plant near the northwest corner of the Site (EG&G 1994g).

The Rocky Flats Alluvium is the main source of sand and gravel at the Site. Approximately 250 million cubic yards of sand and gravel in the Golden area are suitable for concrete and mineral aggregate (Van Horn 1976). The nearest operational sand and gravel quarry (Western Aggregates) is located in the northwest corner of the Buffer Zone. Western Aggregates plans to expand their operations by approximately 1,300 acres to areas immediately north, west, and southwest of the Site. Because Rocky Flats Alluvium is present across the Site, the potential exists for future excavation of sand and gravel. No other mineral resources appear feasible for development at the Site.

The scope of this CID is to provide a recounting of the Site's updated *baseline* and *closure* scenario activities and the relative impacts of these activities to the worker, public, and environment. The CID, therefore, is focused specifically on *baseline* and *closure* activities at the

Site which are initiated by or sponsored through resources of DOE and its contractors. For example, the CID will not describe or otherwise analyze the potential impact to Site operations or its cultural and natural resources of privately owned and operated sand and gravel quarry operations located in the northwest portion of the Buffer Zone. Colorado law provides that subsurface mineral owners have the right to use that part of the surface estate reasonably required to extract and develop the subsurface mineral interests while surface owners have the right to have the subsurface mineral estate developed in a reasonable manner and to have any adverse impacts upon the surface property which are associated with the development of the subsurface mineral estate mitigated. The federal government does not own the subsurface mineral estate in that portion of the Site where a privately owned and operated sand and gravel quarry exists. The Site intends to meet its obligations as a surface owner under Colorado law and will neither support nor hinder the mining activities of a privately owned and operated sand and gravel quarry located in the northwest portion of the Buffer Zone so long as development of the subsurface minerals is reasonable, results in mitigation of adverse impacts to the surface estate, and allows for reasonable use of the surface by the Site.

Age	Formation	Thickness [feet]
Quaternary	Rocky Flats Alluvium/ Colluvium	0-100 feet
Cretaceous	Arapahoe Formation	0-50 feet
	Laramie Formation	600-800 feet upper interval: 300-500 feet
		lower interval: 300 feet
	Fox Hills Sandstone	90-140 feet
	Pierre Shale and older units	>7,000 feet



Clayey Sandy Gravels – reddish-brown to yellowish-brown matrix, grayish-orange to dark-gray, poorly sorted, angular to subrounded cobbles, coarse gravels, coarse sands and gravelly clays; varying amounts of caliche

Claystones, Silty Claystones, and Sandstones – light to medium olive-gray with some dark olive-black claystone, silty claystone, and fine-grained sandstone, weathers yellowish orange to yellowish brown; a mappable, light to olive gray, medium- to coarse-grained, frosted sandstone to conglomerate sandstone occurs locally at the base (Arapahoe marker bed)

Claystones, Silty Claystones, Clayey Sandstones, and Sandstones – kaolinite, light to medium gray claystone and silty claystone and some dark gray to black carbonaceous claystone, thin 2-foot coal beds and thin discontinuous, very fine to medium-grained, moderately sorted sandstone intervals

Sandstones, Claystones, and Coals – light to medium gray, fine- to coarse-grained, moderately to well sorted, silty, immature quartzose sandstone with numerous claystones, and subbituminous coal beds and seams that range from 2 to 8 feet thick

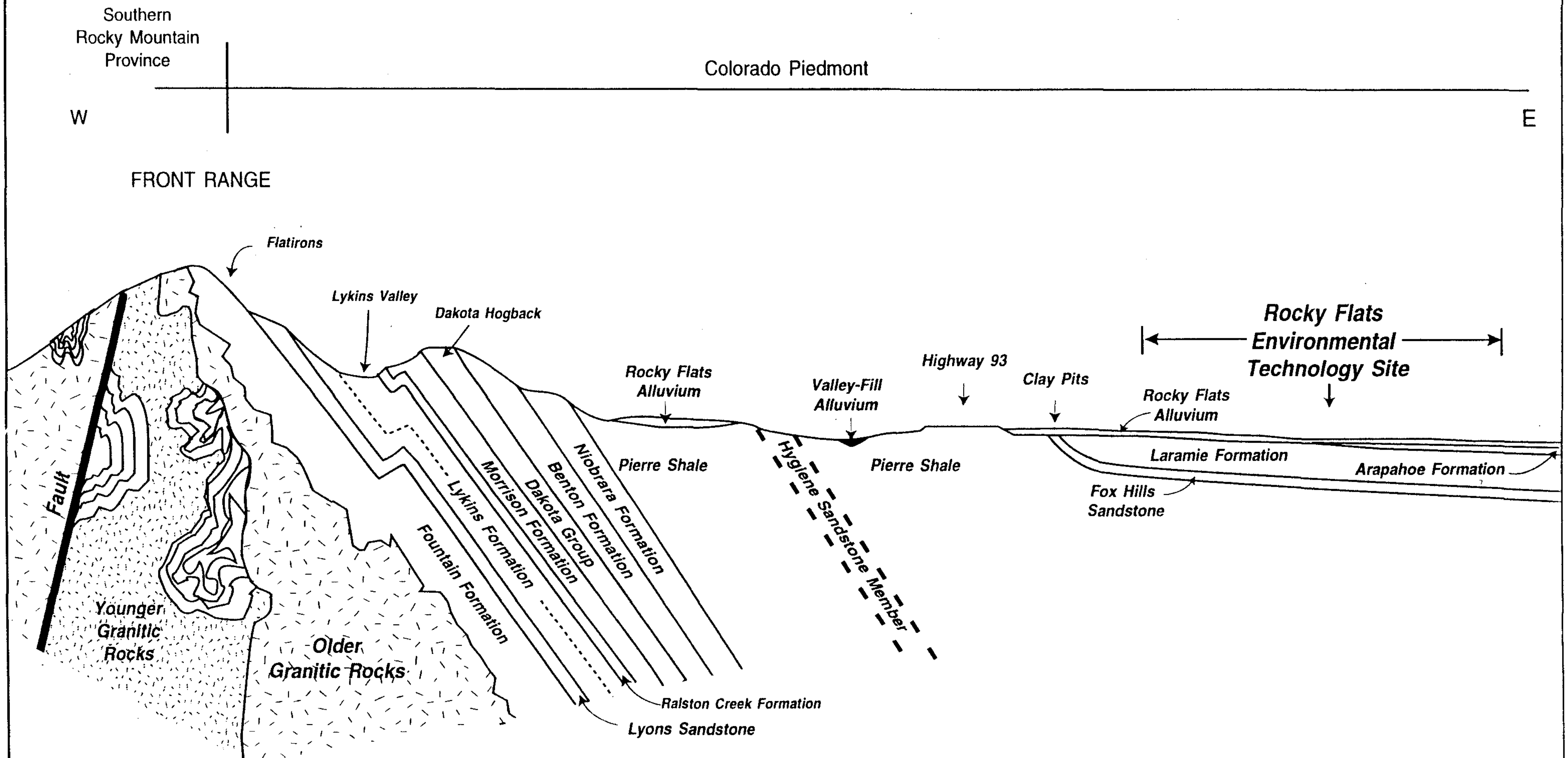
Sandstones – grayish orange to light gray, calcareous, fine-grained, subrounded glauconitic, friable sandstone

U.S. Department of Energy
Rocky Flats Environmental Technology Site,
Golden, Colorado

Generalized Stratigraphic Column for the Site

Source: EG&G 1992c

Figure 4.2-2



(Not to Scale)

U.S. Department of Energy
Rocky Flats Environmental Technology Site
Golden, Colorado

Generalized Geologic Cross-Section of the Site Region

Figure 4.2-3

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4.3 Soils

Soils at the Site have been sampled and studied as part of the Site's soils monitoring program, background soils characterization program, and remedial investigations of various operable units (OU). Soils were also mapped by the U.S. Soil Conservation Service as part of a soil survey of the Golden, Colorado area (Price 1984). Figure 4.3-1 depicts soil types at the Site. Table 4.3-1 summarizes widespread soil types and their properties.

Table 4.3-1. Widespread Soil Types at the Site

Soil Type	Occurrence	Properties	Water/Wind Erosion	Properties Restricting Use[1]
Western Portion of the Site				
Flatirons: Very cobbly to very stony sandy loams. Deep, well-drained.	• Pediments, high terraces, upper hillsides (0-5% slopes) • Predominant soil type in western half of Site, but extends to eastern half	• Permeability: low • Runoff: slow • Composition: 35-80% cobbles by volume	• Water erosion: slight • Wind erosion: slight	• Number of cobbles • Expansive clays (shrinking/swelling)
Nederland: Very cobbly, sandy loam. Deep, well-drained, cobbly to gravely and loamy.	• Fans and terrace escarpments (10-15% slopes) • Valley slope soil in western half of the Site	• Permeability: moderate • Runoff: rapid • Composition: 35-75% cobbles by volume	• Water erosion: severe on steep slopes • Wind erosion: slight	• Slope • Large stones
Eastern Portion of the Site[2]				
Denver-Kutch-Midway: Clay loams. Denver-Kutch moderately deep to deep, well-drained. Midway shallower.	• Most notable in eastern half of Site; but also occurs in western half along valley slopes • Denver-Kutch: lower hillsides along drainages (5-25% slopes) • Midway: steeper slopes	• Permeability: low • Runoff: rapid • Composition: 0-15% cobbles by volume	• Water erosion: severe • Wind erosion: low to moderate	• Depth to bedrock • Expansive clays (shrinking/swelling) • Slope • Low strength • Low permeability
Valmont: Clay loam. Deep, well-drained.	• Northeast corner of Site on eastward extension of divide between Rock Creek and Walnut Creek drainages (0-3% slopes)	• Permeability: low in upper 20-40 inches • Runoff: slow • Composition: 0-15% cobbles by volume	• Water erosion: low • Wind erosion: moderate	• Clay content • Expansive clays (shrinking/swelling) • Low strength
Haverson: Loam.	• Flood plains or low terraces (0-9% slopes)	• Permeability: moderately low • Runoff: medium • Composition: 0-35% cobbles by volume	• Water erosion: moderate • Wind erosion: moderate	• Expansive clays (shrinking/swelling) • Flooding during brief periods in spring and summer
Nunn: Clay loam. Deep, well-drained.	• Lower slopes adjacent to drainage bottoms in eastern portion of the Site	• Permeability: low • Runoff: slow to medium • Composition: 0-15% cobbles by volume	• Water erosion: slight to moderate • Wind erosion: slight to moderate	• Expansive clays (shrinking/swelling) • Low strength • Low permeability

[1] Refers to properties restricting use of a soil type for construction, revegetation, or waste management purposes.
[2] Less-common clay loams along the eastern margin of the Site include soils of the Veldkamp, Englewood, McClave, and Leyden-Primen-Standley associations.

As the above table indicates, soils in the western and eastern portions of the Site are distinctly different. In general, soils at the Site are continually forming from alluvial (stream-deposited), colluvial (gravity-deposited), or exposed bedrock material. Soil textures are predominantly loamy with varying amounts of clay, sand, gravel, and cobbles. Soil types vary in accordance with the geologic materials from which they are formed and their location (pediments, hillsides, valley slopes, or drainage bottoms).

Operations at the Site have introduced contaminants to the soil through waste disposal practices and accidental releases and spills. These contaminants have been distributed primarily by the actions of wind, water, and isolated physical disturbance. Because operations at the Site have involved the manufacture and use of a wide range of substances, the types of contamination vary widely. Some of the primary contaminant types include radionuclides, volatile and semivolatile organic compounds (such as solvents), metals, acids, pesticides, herbicides, polychlorinated biphenyls, and fuel hydrocarbons.

The following sections examine radiological and nonradiological contamination in soils at the Site under baseline conditions.

4.3.1 Deposits of Radionuclides in Soils

Essentially, all plutonium in the environment is artificial, arising from activities of humans. Sources of environmental plutonium can be categorized as "global sources" that have distributed plutonium around the world and "local sources" that have distributed plutonium on a much smaller spatial scale. Global sources include atmospheric nuclear weapons testing and the burn-up of a satellite in the atmosphere. Local sources include releases from nuclear facilities and accidental releases (CDPHE 1994). Americium is also present from fallout as a decay product of plutonium. Uranium is mainly present as a natural component of rocks and soils, and to a lesser degree as a result of atmospheric fallout.

There is no standard at the federal level for transuranic (TRU) radionuclides in soil, however, the EPA has proposed a screening level for plutonium of 44.4 disintegrations per minute per gram (dpm/g), or 19.98 picocuries per gram (pCi/g), based on a soil density of 1 gram per square centimeter for soils sampled to a depth of 1 centimeter (EPA 1977). At the state level, CDPHE adopted a standard for plutonium in 1973 of 2.0 dpm/g, or 0.9 pCi/g, based on a soil density of 1 gram per square centimeter for soils sampled to a depth of 0.25 inch (CDPHE 1973).

Soils in many areas of the Site are not well characterized. In some cases, soil samples have not been collected even for locations known to have been used for storage or handling of radioactive materials. Nevertheless, enough data exist to present an adequate picture of radiological contamination in soils at the Site under baseline conditions.

Plutonium

Deposits of plutonium contamination in soils at and around the Site have been studied since the late 1960s. Although differing in some details, all resulting maps have shown a plume of elevated concentrations of plutonium extending over the eastern portion of the Site and in many cases farther to the east and southeast. Concentrations of plutonium in the soils are highest on the eastern side of the Industrial Area and decrease with distance from this location.

The source of this dispersed plutonium was an area where industrial oil mixed with plutonium was stored in steel drums from 1958 to 1968. This oil and plutonium mixture leaked on to the soils at the storage area. Plutonium particles entrapped in the topsoil were carried by winds and deposited on soils to the east and southeast. It has been estimated that the oil contained 86 grams of plutonium (roughly a fifth of a pound) (Litaor 1995). Remediation of the storage area was undertaken in 1968, and the area was capped with asphalt to prevent further release of contaminated soils. This capped area is known as the 903 Pad (IHSS 112) and is within the inner buffer zone.

Radiological soil sampling programs were conducted from 1972 to 1978 and from 1983 to the present. Soil samples were collected from locations situated along two concentric circles, one with a radius of approximately 1 mile and the second with a radius of approximately 2 miles from the center of the Industrial Area.

Samples taken in 1994 from the inner concentric circle ranged from 0.029 pCi/g to 9.2 pCi/g. Samples from the outer concentric circle ranged from 0.011 pCi/g to 3.5 pCi/g. Consistent with expectations, the highest plutonium concentrations were found in soil samples from the eastern portion of the Buffer Zone, with the contamination trending east to southeast and concentrations decreasing with distance from the Industrial Area (Kaiser-Hill 1995a). Figure 4.3-2 shows average plutonium concentrations at the Site and in the vicinity for the past 10 years.

Residual deposition (global fallout) of plutonium from past atmospheric testing of nuclear weapons in the Denver Metropolitan Area has been estimated at 0.017 pCi/g. The mean and highest measured concentrations from deposition of plutonium in the Denver Metropolitan Area are 0.04 and 0.08 pCi/g, respectively (Litaor 1995). Table 4.3-2 compares minimum and maximum plutonium concentrations at the Site to this residual plutonium deposition.

An evaluation was conducted on environmental activities at Rocky Flats by Rocky Mountain Remediation Services (RMRS). In June through September 1996, a review on the actinide migration work was conducted by an academic panel. The panel advised and provided recommendations to Rocky Flats on the current status of actinides in soils and water issues at the site. This effort will continue minimally in 1997.

Table 4.3-2. Comparison of Plutonium Concentrations at the Site to Denver Metropolitan Area Residual Deposition

	Site–One-Mile Radius		Site–Two-Mile Radius		Denver Metropolitan Area	
	Minimum	Maximum	Minimum	Maximum	Average	Maximum
Plutonium (pCi/g)	0.04	18.8	0.02	4.5	0.04	0.08

Americium

Americium in soils at the Site has not been studied as intensively as plutonium. Available data show that the spatial distribution of soils with deposits of americium overlaps with that of the soils with plutonium deposits. Because americium is a decay product of plutonium, this is to be expected. Nearly all of the americium in the soil around the Site has resulted from radioactive decay of plutonium. Levels of americium are expected to increase over time as more of the plutonium decays.

Uranium

The distribution of uranium in soils at the Site has also been studied and mapped. However, the spatial distribution of uranium is not clearly related to contaminant source areas (i.e., areas at which spills and disposals are known to have occurred) and is not consistent with the wind dispersal mechanism identified for plutonium and americium. The greater mobility of uranium has been proposed as an explanation for the irregular spatial distribution of uranium contamination. Uranium is commonly transported in a dissolved form in surface water runoff from rainfall and snowmelt, whereas plutonium is relatively insoluble and adheres very strongly to soil particles. Plutonium usually remains attached to the soil and is only transported if the soil particle is transported.

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In most soils at the Site, quantities of uranium fall within the background range. The average background level for uranium isotopes is 1.097 pCi/g for uranium-233/-234, 0.0539 pCi/g for uranium-235, and 1.09 pCi/g for uranium-238 (Litaor 1995).

Uranium has been found on occasion at levels indicative of "hot spots." Hot spot removal of soils with deposits of uranium occurred at the 881 Hillside in 1994, and similar hot spot removal may be included in future remedial actions.

4.3.2 Nonradiological Soil Contamination

Nonradiological chemical contamination has been identified in soils at the Site through various sampling programs and operable unit investigations. Chemicals identified include metals with concentrations exceeding background levels and organic chemicals that are not naturally occurring. Background levels were derived from the *Background Geochemical Characterization Report* (EG&G 1993g). In all cases, organic constituents were assumed to be anthropogenic (human-caused) in origin and not attributable to background levels.

Analytical results of soil sampling and contamination identification have been published in RCRA Field Investigation reports for IHSSs within the inner and outer buffer zones. Characterization of soils has not been completed for IHSSs within the Industrial Area.

4.4 Water

This section describes 1) ground water characteristics, 2) ground water quality, 3) surface water characteristics, and 4) surface water quality at the Site under baseline conditions. The information provided is based on the Integrated Water Management Plan (DOE 1996q), Groundwater Conceptual Plan (DOE 1996r), Draft Integrated Monitoring Plan (DOE 1997), Pond Operation Plan (DOE 1996n), and Hydrogeologic Characteristic Report (EG&G 1995q).

4.4.1 Ground Water Characteristics

Regional Hydrogeology

The Denver Groundwater Basin is a regional aquifer system which extends beneath approximately 6,600 square miles of land in Colorado. In general, it is bounded by the Front Range of the Rocky Mountains to the west, Limon to the east, Greeley to the north, and Colorado Springs to the south. An aquifer is defined as any geologic formation, group of formations, or portion of a formation that is saturated and sufficiently permeable to yield substantial and usable quantities of ground water to wells or springs (Fetter 1988).

Land-surface elevations within the Denver Basin range from 4,500 feet in the northeast to 7,500 feet in the south. Except for the extreme southern portion of the basin, surface drainage is toward the north and northeast. Mean annual precipitation varies from 11 inches along the northeast margin of the basin to 18 inches along the southern and western margins. Perennial streams and associated irrigation ditches are important sources of recharge water to aquifers in the Denver Basin (recharge is the process by which an aquifer is replenished during seasonal runoff or precipitation).

Water-bearing strata within the Denver Basin (from oldest to youngest) consist of the Fox Hills Sandstone, Laramie Formation, Arapahoe Formation, Denver Formation, Dawson Arkose Formation, and Quaternary alluvial deposits. Figure 4.4-1 shows the generalized cross-section of the stratigraphy underlying the Site. In stratigraphic sequence from oldest to youngest, bedrock aquifers within the Denver Basin consist of the Laramie-Fox Hills Aquifer, Arapahoe Aquifer, Denver Aquifer, Dawson Aquifer, and Regional Alluvial Aquifer. With the exception of the Denver and Dawson Aquifers, all are present at the Site. These aquifers and their location with respect to the Site are shown in Figure 4.4-2 and Figure 4.4-3.

The Site is situated on the northwestern margin of the Denver Basin and overlies the Arapahoe Aquifer. This is a potential recharge area for the Arapahoe Aquifer. As shown in Figure 4.4-4, ground water in the Arapahoe Aquifer flows from recharge areas along the margin of the Denver Basin eastward toward the South Platte River.

Ground water levels in the bedrock aquifers within the Denver Basin are typically more than 100 feet below land surface. Ground water in the Regional Alluvial Aquifer is generally near land surface and is affected by interaction with surface water.

Local Hydrogeology

The Site's local hydrogeology is characterized on the basis of its two distinct hydrostratigraphic units—the upper hydrostratigraphic unit (or "uppermost aquifer") and the lower hydrostratigraphic unit (or "lower aquitard"). A hydrostratigraphic unit is defined as a formation, part of a formation, or group of formations with similar hydrologic characteristics that allows for grouping into aquifers or confining layers (Fetter 1988).

An aquifer has sufficient permeability or hydraulic conductivity to permit water to flow through it with relative ease, thus enabling it to provide a usable quantity of water to a well or spring. An aquifer serves two functions, one as a conduit through which water flows, and the other as a water storage reservoir. An aquitard or confining layer (e.g., shale, clay, silt) can also store large quantities of water but is characterized by low hydraulic conductivity, meaning that water does not readily pass through it. Figure 4.4-1 depicts the hydrostratigraphy at the Site.

The distinction between the uppermost aquifer and the lower aquitard at the Site is based on their contrasting hydraulic conductivities. Hydraulic conductivity refers to the ease with which water can pass through a rock unit (such as sandstone, limestone, granite, etc.). It is hydraulic conductivity that allows an aquifer to serve as a conduit for water flow. Hydraulic conductivity can vary both horizontally (laterally) and vertically (up and down) for rocks and aquifers. Since sedimentary strata are deposited in horizontal layers, hydraulic conductivity is generally greater horizontally than vertically, commonly by several orders of magnitude.

The lower aquitard has markedly lower hydraulic conductivities than the uppermost aquifer. This contrast determines the nature of ground water flow at the Site. The hydraulic conductivity of the lower aquitard limits downward movement of ground water and produces lateral flow within the more conductive uppermost aquifer (EG&G 1994t).

The uppermost aquifer and lower aquitard at the Site are briefly characterized below.

UPPERMOST AQUIFER. The uppermost aquifer is comprised of the unconfined saturated portions of strata (unconsolidated and consolidated) at the Site. An unconfined aquifer has a free water surface that rises and falls in response to recharge and discharge rates. A confined aquifer is overlain and underlain by confining layers (or aquitards). The designation of the uppermost aquifer, as defined above, is equivalent to the term "upper hydrostratigraphic unit" commonly used in various Site reports.

Unconsolidated surficial materials in the uppermost aquifer range in thickness from 0 feet along portions of the valley slopes to greater than 100 feet near the western boundary of the Site. These near-surface aquifers consist of the upper weathered portions (generally 15 feet thick) of the Laramie and Arapahoe Formations and the unconsolidated stream- and gravity-deposited materials that overlie them.

Recharge to the uppermost aquifer occurs primarily from precipitation, but streams, ditches, and ponds also supply recharge. Recharge to the uppermost aquifer varies seasonally. Ground water elevations typically peak in May, then decline throughout the summer and autumn when recharge from precipitation diminishes. Many wells within the uppermost aquifer are dry during much of the year, indicating that the material is unsaturated (i.e., that ground water is not constantly present). Figure 4.4-5 shows the water table for the uppermost aquifer during the spring of 1993.

Ground water within the uppermost aquifer is generally unconfined but is locally confined within weathered bedrock. Ground water flow within the uppermost aquifer is largely controlled by the topography of the bedrock surface. On terraces and terrace ridges, it generally flows to the east-northeast. In areas dissected by east-trending stream drainages, it flows to the north and south into the drainages. In the bottoms of the drainages, it flows to the east.

Much of the shallow saturated material at the Site does not constitute an aquifer in the classic sense, because the yield of water to wells is typically low and broad areas often become dry during autumn and early winter months. Nevertheless, these shallow saturated materials may be capable of transporting contamination that could pose a risk to human health or the environment. Potential contaminant pathways are unique to each operable unit at the Site.

LOWER AQUITARD. The lower aquitard is comprised of the deeper sandstone and claystone confining layers of the Laramie and Arapahoe Formations. The designation of the lower aquitard, as defined above, is equivalent to the term "lower hydrostratigraphic unit" commonly used in various Site reports.

The lower aquitard is composed of unweathered bedrock of the Laramie and Arapahoe Formations. These bedrock formations consist primarily of claystone with lesser amounts of siltstone and a relatively small percentage of discrete sandstone lenses. Combined, the Laramie and Arapahoe Formations are 600 to 800 feet thick beneath the Industrial Area. Recharge occurs directly from precipitation in the western portion of the Site where bedrock is exposed or through downward ground water flow from the uppermost aquifer. Ground water within the lower aquitard is generally confined but can also be unconfined depending on the location. Flow within the lower aquitard is from west to east.

BENEATH THE LOWER AQUITARD. The regional Laramie-Fox Hills Aquifer is present at greater depth below the Site under confined conditions and represents a third distinct hydrostratigraphic unit at the Site. The Laramie-Fox Hills Aquifer is composed of the lower sandstone unit of the Laramie Formation and the underlying Fox Hills Sandstone. These sandstone units are locally exposed in excavated pits along the western boundary of the Site, where the aquifer is recharged principally by precipitation. The Laramie-Fox-Hills Aquifer dips to the east beneath the Industrial Area. The aquifer is separated from the uppermost aquifer under the Industrial Area by 800 to 900 feet of low-permeability claystones, siltstones, and sandstones of the Laramie Formation (the lower aquitard).

ESTIMATED QUANTITY OF GROUND WATER BENEATH THE SITE. A preliminary estimate of the average annual quantity of ground water stored beneath the Site is presented in Table 4.4-1 (EG&G 1994t). Stored ground water levels can vary seasonally and with the type of hydrologic unit involved. Bedrock units have relatively constant water levels, while alluvial and valley hydrologic units tend to exhibit variations in water levels over a normal year.

Table 4.4-1. Estimated Quantity of Ground Water Beneath the Site

Hydrostratigraphic Unit	Area (acres)	Average Thickness (feet)	Average Saturated Thickness (feet)	Water in Storage[1] (acre-foot)	Estimated Quantity (gal)
Alluvium and Valley Fill[2]	6,470	Not estimated	10	19,400	6.3 billion
Arapahoe Formation[3]	4,970	35	35	52,200	17.0 billion
Laramie-Fox Hills[3]	6,350	200	120	228,600	74.5 billion
Total	–	–	–	**300,200**	**97.8 billion**

[1]An acre-foot is the volume of water that would cover one acre to a depth of one foot. Volumes are calculated based on an assumed porosity of 0.3.
[2]Alluvial and Valley Fill units were treated as a single hydrologic unit. Average saturated thickness was estimated from the difference between Alluvial and Valley Fill ground water elevation and bedrock elevation throughout the Site.
[3]Ground water storage estimates are only for the hydrologic unit listed.

POTENTIAL GROUND WATER CONTAMINANT PATHWAYS. Water (and any potential contaminants it may contain) arrives in an aquifer through one of several primary means:

- Direct infiltration or precipitation (the major source).
- Infiltration from surface water.
- Interaquifer leakage, or flow from one aquifer to another (probably the predominant source in deeper confined aquifers).
- Infiltration from artificial sources such as detention ponds, surface water impoundments, sewer lines, and dry wells.

The water may contain contaminants as it enters an aquifer or may leach contaminants from subsurface sources.

The Site has detention ponds, surface water impoundments (e.g., the Solar Evaporation Ponds), buried sewer lines, and dry wells, all of which represent potential artificial sources for infiltration of contaminants to the ground water. In addition, past disposal practices at individual hazardous substance sites may have impacted ground water quality at the Site. Site ground water monitoring and quality issues are discussed below.

Before 1994, the hydraulic conductivity of the claystones between the uppermost aquifer and the lower aquitard was believed to be sufficiently low to ensure that Site contaminants could not have migrated vertically to the lower formations under the Site. In 1994, borehole correlation work indicated the potential for near-surface faults to exist (i.e., there may be flow pathways between the uppermost aquifer and the Laramie-Fox Hills Aquifer). Additional hydrogeologic characterization is being performed to assess these potential pathways (Kaiser-Hill 1995a).

4.4.2. GROUND WATER QUALITY

GROUND WATER MONITORING

The Site Groundwater Monitoring Program includes a network of wells installed to satisfy the dual objectives of groundwater characterization and compliance monitoring. The groundwater conceptual plan (DOE 1996r) provides a basis for cleanup and management of contaminated groundwater at the Rocky Flats Environmental Technology Site (Site). The plan also describes management and cleanup of contaminated groundwater for the Accelerated Site Action Plan scenarios.

Characterization objectives include identifying upper and lower hydrostratigraphic units; evaluating ground water pathways and migration characteristics; qualifying the relationship between ground water and surface water at the Site; and identifying the relationship between precipitation, infiltration, and ground water recharge at the Site. Additional objectives include establishing background analyte concentrations and characterizing background geochemical interactions.

Compliance monitoring objectives include determining background values, measuring the concentration of hazardous constituents, measuring hydrologic parameters of aquifers and aquitards, and providing data for estimating the rate of movement and extent of any contaminant plumes in the aquifers beneath the Site. Analyses derived from the Ground Water Monitoring Program provide the means for evaluating the impacts of Site operations on ground water and limiting concentrations that may adversely affect the quality of ground water in the area.

In 1996 an Integrated Water Management Plan project was initiated to evaluate the groundwater program with the goal of integrating all groundwater monitoring requirements into an unified Sitewide network. This project was also integrated with the new RFCA strategy for Site monitoring requirements established in the Action Level Framework attachment to RFCA.

A Data Quality Objective process was used to establish the proper decision criteria under which this unified program would address requirements. A stakeholder workgroup was established and all decisions were negotiated both on a technical basis and a compliance basis. The monitoring program will be integrated with ongoing activities designed to protect against groundwater impact to surface water by reducing or eliminating the potential for contamination. The activities may include identification of potential contaminants, identification of contaminant sources, identification of contaminant pathways, monitoring contaminant concentration, monitoring of remedial actions, and protection from sources of contamination.

WELLS AT THE SITE. By the end of 1994, there were approximately 700 wells at the Site, 352 of which were sampled on a regular basis. Approximately 150 of the wells were installed during 1993 to support increased ground water monitoring activities in various operable units at the Site. At the end of 1996, there were about 1000 wells at the Site.

In 1996 groundwater monitoring program consisted of 152 monitoring wells. Sixty-nine wells are sampled quarterly and 83 wells are sampled semiannually. This plus 38 Quality Assurance samples equated to 480 sample events each year. A standard analysis suite was used for all wells. A new sampling program, recently negotiated with EPA & CDPHE, specifies that 89 wells will be sampled semiannually for a unique suite of analyses, and 63 Quality Assurance samples and resamples will be taken starting in fiscal year 1997.

The groundwater monitoring network, as defined in the Draft Integrated Monitoring Plan (DOE 1997), introduces seven categories of monitoring wells. The well types and decision rules are defined below:

Plume Definition Monitoring Wells: These wells are located within known contaminant plumes and are above Tier II established in the Action Level Framework of the Rocky Flats Clean Up Agreement for Groundwater (Tier II action level = maximum contaminant level), but are below the Tier I action levels (Tier I action level = 100 x the maximum contaminant level).

Plume Extent Monitoring Wells: These wells are located at the edges of known groundwater contaminant plumes along pathways to surface water. These wells monitor for an increase in

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concentrations of contaminants that may result in future impacts to surface water. If action levels are exceeded for three consecutive months, then appropriate parties are notified and the possible impacts to surface water are evaluated.

Drainage Monitoring Wells: These wells are located in stream drainages, downgradient of contaminant plumes. If action levels are exceeded the possible impacts to surface water are evaluated.

Boundary Monitoring Wells: These wells monitor groundwater leaving the eastern Site boundary through the stream drainage channels.

Deactivation and Decommissioning Monitoring Wells: These wells monitor for releases to groundwater from D&D activities.

Performance Monitoring Wells: These wells monitor the effect of a remediation or source removal action on groundwater as required in the Action Level Framework.

RCRA Monitoring Wells: These wells monitor downgradient groundwater contaminant concentrations at RCRA units. If the mean concentrations of a contaminant in a downgradient well exceed the mean concentration in upgradient wells, an investigation will be initiated to investigate possible causes.

The locations of monitoring wells are depicted in Figure 4.4-6. As shown in the figure, wells are distributed throughout the Site to provide the necessary coverage to satisfy RCRA and CERCLA requirements and Site protection guidelines for monitoring ground water at hazardous waste sites.

BACKGROUND GROUND WATER SAMPLING. Background ground water samples are collected from wells known to be unaffected by operations at the Site. The background ground water samples are used for comparison purposes to help identify impacts to ground water quality at the Site. Groundwater samples collected from operable units are compared statistically to background samples to identify analytes present at concentrations greater than background levels. If an analyte is determined to be at concentrations above background levels at an operable unit, the ground water is considered affected and the analyte is considered a potential contaminant.

SAMPLING FOR CHEMICAL CONSTITUENTS. Groundwater samples are collected from alluvial and bedrock wells and analyzed at off-site laboratories for the parameters listed in Table 4.4-2 (Kaiser-Hill 1995a). Quarterly water-level measurements are also taken to adequately assess ground water flow directions and magnitudes. These data are used to evaluate trends in ground water quality and contaminant migration in the ground water.

Table 4.4-2. Typical Site Chemical Constituents Monitored in Ground Water

Metals	Tin	Ethyl Benzene	**Total Radionuclides**
Aluminum	Vanadium	2-Hexanone	Americium-241
Antimony	Zinc	4-Methyl-2-pentanone	Plutonium-239 and -240
Arsenic		Methylene Chloride	
Barium	**Volatile Organic**	Styrene	**Indicators**
Beryllium	**Compounds**	1,1,2,2-	Total Dissolved Solids
Cadmium	Acetone	Tetrachloroethane	
Calcium	Benzene	Tetrachloroethene	**Field Parameters**
Cesium	Bromodichloromethane	1,1,-Trichloroethane	Alkalinity
Chromium	Bromoform	1,1,2-Trichloroethane	Dissolved Oxygen
Cobalt	Bromomethane	Trichloroethene	(discontinued in
Copper	2-Butanone	Toluene	1993)
Iron	Carbon Disulfide	Total Xylenes	pH
Lead	Carbon Tetrachloride	trans-1,2-Dichloroethene	Specific Conductance
Lithium	Chloride	trans-1,3-	Temperature
Magnesium	Chlorobenzene	Dichloropropene	
Manganese	Chloroethane	Vinyl Acetate	**Anions**
Mercury	Chloroform		Bicarbonate
Molybdenum	Chloromethane	**Dissolved**	Carbonate
Nickel	cis-1,3-Dichloropropene	**Radionuclides**	Chloride
Potassium	1,1-Dichloroethane	Cesium-137	Cyanide
Selenium	1,2-Dichloroethane	Gross Alpha	Fluoride
Silver	1,1-Dichloroethene	Gross Beta	Nitrate/Nitrite
Sodium	1,2-Dichloroethene	Radium-226 and -228	Orthophosphates
Strontium	(Total)	Strontium-89 and -90	Sulfate
Thallium	1,2-Dichloropropane	Tritium	
	Vinyl	Uranium-233, -234, -	
	Dibromochloromethane	235, and -238	

WELL ABANDONMENT. During 1993, monitoring well abandonment and replacement under the Well Abandonment and Replacement Program was initiated at the Site. This program was developed to mitigate the potential for contaminant migration through improperly constructed or damaged wells. Thirty-four monitoring wells in 1993 and 39 wells in 1994 were abandoned under this program. No wells were abandoned in 1995 but 5 wells were abandoned in 1996.

Ground Water Quality in the Uppermost Aquifer

Ground water investigation and restoration activities at the Site follow a phased approach: contamination is identified, treatment procedures are designed and implemented, and the adequacy of restoration actions is monitored. Currently, groundwater is assessed with respect to the upper tolerance limits established in the *Background Geochemical Characterization Report* (EG&G 1993g).

The uppermost aquifer at the Site is designated as an aquifer for compliance purposes, however, many weathered-bedrock wells within the uppermost aquifer have slow water-level recovery times following ground water sampling. This is indicative of low ground water yield. Yields for wells completed in unconsolidated surficial deposits are typically less than one gallon per minute.

Figure 4.4-7 displays the known locations of known or suspected contamination plumes in the uppermost aquifer. Ground water contamination is most consistently detected within operable units. Ground water wells in the vicinity of the Solar Evaporation Ponds (OU4) consistently exhibit the highest concentrations for the most chemicals. Wells near the 903 Pad and East Spray

Fields in OU2 display the highest concentrations of plutonium-239/-240 and americium-241. Ground water near OU1 (881 Hillside) shows high concentrations of volatile organic compounds and metals. Ground water wells not related to operable units and located in the Buffer Zone generally do not yield waters with any notable contamination, though some isolated instances of potential contamination do exist.

Chemicals presented as potential contaminants include metals with concentrations exceeding background levels and organic chemicals that are not naturally occurring. In all cases, organic constituents in the target analyte group are assumed to be anthropogenic (human-caused) in origin and not attributable to background levels.

Ground Water Quality in the Lower Aquitard

Generally, lower aquitard ground water is not as affected by surface sources of contamination as that of uppermost aquifer ground water at the Site. This is in part due to the limited hydraulic connection and ground water interaction between the uppermost aquifer and the lower aquitard. However, localized ground water interaction does occur. The limited presence of volatile organic compounds and other contaminants in the lower aquitard indicates that it is being affected by contaminated ground water in the uppermost aquifer.

The localized nature of contamination in unweathered bedrock, combined with existing hydraulic conductivity and water-level data, illustrate the following aspects of flow for the lower aquitard (or lower hydrostratigraphic unit):

- Contaminant detections are usually localized. There are no defined plumes in the lower aquitard.
- The lower hydrostratigraphic unit fits the definition of an aquitard, which is a confining bed that retards but does not prevent the flow of water to or from an adjacent aquifer. An aquitard does not readily yield water to wells or springs, but may serve as a storage unit for ground water. Measured hydraulic conductivities in the lower aquitard are on the order of 10^{-7} cm/sec, which are similar to conductivities expected from engineered clay barriers.
- Given the hydraulic conductivity of the lower aquitard, substantial transport of contaminants is not expected.

Because of the low hydraulic conductivities exhibited within the lower aquitard and the thickness of the strata within this unit, there is no defined pathway for contaminants in the uppermost aquifer or lower aquitard to migrate downward into the Laramie-Fox Hills Aquifer. It is apparent from the available data that the low permeability and great thickness of the claystone, combined with steep vertical hydraulic gradients, reflect a condition of poor hydraulic communication between aquifers across the lower hydrostatic unit.

Characterization studies indicate that ground water flow in the lower aquitard is predominantly eastward and generally restricted to discontinuous sandstone and siltstone lenses. Bedrock wells monitoring ground water in these sandstone and siltstone lenses were used to assess the quality of lower aquitard ground water flowing off-site. Water in the lower aquitard of the Site's eastern boundary exhibits little or no impact from the Site's activities.

The Laramie-Fox Hills Aquifer is a third distinct hydrogeologic unit beneath the Site and is used for drinking water supply in the Denver area. Some potential for water and contaminant transport along fault zones is postulated; this possibility may be examined in future Site investigation activities.

4.4.3 Surface Water Characteristics

This section describes surface water drainages, detention ponds, seeps, and dams at the Site under baseline conditions.

The Site is situated within the headwaters of two regional drainage basins: Boulder Creek basin and Big Dry Creek basin. Three intermittent streams within these basins drain the Site: Walnut Creek, Woman Creek, and Rock Creek. Walnut Creek and Woman Creek flow eastward across the central and southern portions of the Site, respectively, and are within the Big Dry Creek basin. Rock Creek drains the northern portion of the Site and flows northeastward into the Boulder Creek basin.

Upstream surface water is conveyed around or through the Site via several canals or ditches. The South Boulder Diversion Canal is located west of the Site and supplies raw water to the Site and to Ralston Reservoir, which contains Denver water supply and is located 5 miles southwest of the Site. Last Chance Ditch, Upper Church Ditch, McKay Ditch, and Kinnear Ditch tap and divert water from Coal Creek (situated west of the Site) around the Site. The South Interceptor Ditch intercepts runoff from the southern portion of the Industrial area and routes it to Pond C-2.

Past production and disposal activities at the Site have influenced Walnut Creek and Woman Creek. The hydrologic response of both drainages to precipitation events has been impacted by development of the Site. Areas now covered by impervious materials (i.e. parking lots and buildings) allow less infiltration. Runoff from the developed areas to these drainages occurs faster and with greater volumes than under natural conditions. The Rock Creek basin is located entirely outside the limits of the Industrial Area and has remained essentially undisturbed. Figure 4.4-8 depicts the creeks and basins at the Site. Table 4.4-3 summarizes the characteristics of the Walnut and Woman Creek basins (EG&G 1991a).

Table 4.4-3. Walnut Creek and Woman Creek Basin Characteristics

Item	Walnut Creek	Woman Creek
Basin area	2,375 acres	2,886 acres
Basin length	5.7 miles	5.7 miles
Basin slope	0.027 foot per foot	0.028 foot per foot
Existing impervious area	14%	2%
Infiltration (Initial)	3.7 inches per hour	3.6 inches per hour
Infiltration (Final)	0.6 inch per hour	0.6 inch per hour

In general, streams at the Site gain water during the spring due to precipitation, recharge, and rising ground water levels. Streams lose water during late summer and autumn due to diminished precipitation, infiltration into unsaturated channel material, and falling ground water levels (DOE 1994g). Stream channels at the Site are often dry in the late summer and autumn.

Walnut Creek

Walnut Creek is an east-flowing, intermittent stream that drains the central portion of the Site, including most of the Industrial Area and the Protected Area. Within Site boundaries, Walnut Creek includes three major branches: South Walnut Creek, North Walnut Creek, and a northern tributary locally referred to as the "unnamed tributary." These tributary streams converge in the eastern portion of the Site.

Walnut Creek headwaters are on the broad Rocky Flats pediment between Coal Creek and the western boundary of the Site. The drainage basin upgradient of Indiana Street covers approximately 2,375 acres. Walnut Creek currently terminates in the Broomfield Diversion Canal; the creek previously flowed into Great Western Reservoir approximately 1 mile east of the Site. The canal was constructed in 1992 to divert flow away from Great Western Reservoir. Flow rates measured at Indiana Street in 1992 ranged from 0 to 11 cubic feet per second and were highest during the spring. The stream is typically dry during much of the late summer, fall, and winter (EG&G 1993a).

The topography and hydrology of Walnut Creek vary considerably within the drainage basin. The western portion of the basin has low relief and a gradient of approximately 2%. Soils in this area are developed from coarse Rocky Flats Alluvium and have high infiltration rates. In the central portion of the basin, channels become better developed where the tributary streams have cut through the Rocky Flats Alluvium into underlying bedrock. In this area, the basin has a gradient of 4%, and stream channels have formed gullies with sideslopes of up to 20%. Soils in this area are fine grained and have low to moderate infiltration rates. The eastern portion of the basin is characterized by the return to a lower gradient (2%) and broad valley floors with shallow sideslopes of about 5%. Soils in this area have low to moderate infiltration rates, resulting from the fine-grained bedrock parent material.

Woman Creek

The Woman Creek basin covers 2,886 acres upgradient of Indiana Street. This east-flowing stream system drains the southern portion of the Site and extends eastward to Standley Lake. Currently, most of the flow in Woman Creek is diverted via the Mower Ditch into Mower Reservoir east of Indiana Street. Water that is not collected by the ditch or that overflows Mower Reservoir continues toward Standley Lake.

The headwaters of Woman Creek are on the Rocky Flats pediment southwest of the Site. In its upper reaches, Woman Creek consists of two branches. The northwestern channel receives water from surface runoff, shallow ground water, Kinnear Ditch, and leakage in the Boulder Diversion Ditch crossover structure. The southwestern channel receives water from runoff and shallow ground water as well as water from the Rocky Flats Lake via Smart Ditch No. 2. The two branches of Woman Creek converge approximately 1.5 miles east of Colorado Highway 93 (Fedors 1993).

In most respects, the Woman Creek basin is very similar to the Walnut Creek basin. Upper reaches are characterized by shallow or indistinct channels and a low gradient. Soils in this area have high infiltration rates that reflect their origin from coarse Rocky Flats Alluvium. Middle reaches are more incised and have both steeper gradients and steeper sideslopes. In its lower reaches, beyond the Site terrace escarpment, the stream occupies a broad, gently sloping valley. Soils in the middle and lower reaches of the basin have low infiltration rates resulting from fine-grained bedrock or reworked alluvium parent material. Flow rates in Woman Creek at Indiana Street in 1992 varied from 0 to 8 cubic feet per second (EG&G 1993a) and are typically highest in the spring. Much of the stream channel is dry during late summer, fall, and winter.

Rock Creek

Rock Creek drains the northwest portion of the Buffer Zone. The portion of the Rock Creek basin south of State Highway 128 (which forms the northern boundary of the Site in this area) is approximately 1,855 acres. Similar to Woman Creek and Walnut Creek, the Rock Creek drainage is characterized by relatively flat headwater areas on the pediment to the west and steep gullies and stream channels to the east where they have cut into the bedrock formations. A northeast-trending ridge separates the Rock Creek drainage from the adjacent Walnut Creek system to the south. This ridge topographically isolates Rock Creek from the developed areas within the Site, and Rock

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Creek receives no water from the Industrial Area. Surface water in Rock Creek originates from precipitation, shallow ground water, and discharge from Western Aggregates, a gravel operation located near the west Site Buffer Zone fence. Rock Creek flows northeastward to its confluence with Coal Creek. Measurements in 1992 show flow rates ranging from 0 to 8 cubic feet per second, with peak flows in the spring (EG&G 1993a).

Surface Water Detention Ponds and Treatment Systems

Surface water in the Walnut Creek and Woman Creek drainages is collected and analyzed in a series of detention ponds prior to being discharged from the Site. The purpose of these detention ponds is to control runoff and prevent pollution of downstream waters.

Runoff from the industrial area is routed through ditches and storm sewers into the Site's twelve constructed detention ponds. In addition, nonindustrial wastewater is treated at the sanitary wastewater treatment plant, which discharges to Pond B-3. All treated wastewater, along with industrial area stormwater runoff, and limited ground water discharges to receiving streams and is stored in various ponds prior to off-site discharges. The stream channels below each pond are usually dry or almost dry except during a batch release. In addition to the ponds at the Site, the Woman Creek Reservoir (just east of the Site) was completed in 1996 to provide additional protection for Standley Lake from Woman Creek drainage flows. Figure 4.4-9 shows the routing schematic for routine pond operations at the Site.

The detention pond systems for Walnut Creek and Woman Creek are further described below.

Walnut Creek Surface Water Flow

The three on-site branches of Walnut Creek—North Walnut Creek, South Walnut Creek, and the unnamed tributary—have been modified to some extent by diversion, channelization, construction of detention ponds, and placement of fill material.

North Walnut Creek contains four detention ponds (referred to as the A-series ponds), which were constructed as part of runoff control and pollution prevention programs at the Site. North Walnut Creek receives surface water runoff and some seepage water from the northern portion of the Industrial Area and adjacent areas. The McKay Bypass Canal diverts water from the upper reaches of North Walnut Creek around the Site to a point downstream of Pond A-4, the terminal pond in the series (see Figure 4.4-9). Ponds A-1 and A-2 are isolated from North Walnut Creek at the A-1 bypass and are maintained for emergency spill control for the northern portion of the Industrial Area; water is not released downstream of these ponds. Pond A-3 water is released downstream to Pond A-4 where it is tested and treated (if necessary) prior to being discharged off-site to North Walnut Creek. This runoff control system is operated in compliance with the Site's National Pollutant Discharge Elimination System (NPDES) permit, the Federal Facilities Compliance Agreement, and the Agreement in Principle (EG&G 1994b).

South Walnut Creek's headwaters are within the Protected Area. This drainage has been altered substantially by development of the Industrial Area and the B-series detention ponds. South Walnut Creek receives surface water runoff and some seepage water from the central portion of the Industrial Area and adjacent areas. A pipeline diverts surface water flow from the headwaters of South Walnut Creek around Ponds B-1, B-2, and B-3 to Pond B-4. Ponds B-1 and B-2 are maintained primarily for emergency spill control for the central portion of the Industrial Area. Pond B-3 receives effluent from the Site's waste water treatment plant; the effluent is released to Pond B-4 on a daily basis. Pond B-4 is a controlled flow-through pond. All flow is conveyed to Pond B-5, the terminal pond on South Walnut Creek. Water quality sampling and analysis are conducted at Pond B-5 prior to transfer to Pond A-4 for final discharge off-site.

The Unnamed tributary (the northernmost of Walnut Creek's three branches) includes the landfill pond in OU7 (Present Landfill). The landfill pond collects seepage from the landfill and runoff from adjacent slopes. Spray evaporation was historically used to reduce water volume within the landfill pond; currently, excess water is piped into North Walnut Creek, thereby preventing discharge to the unnamed tributary (DOE 1994e).

An additional pond on Walnut Creek (the flume pond) located immediately west of Indiana Street is not part of the NPDES system but is used for measurement of surface water flow. From Pond A-4 to Indiana Street, Walnut Creek is typically dry except when water is being discharged from Pond A-4, which occurs every 45 days on average.

Woman Creek Surface Water Flow

Two detention ponds have been constructed on the historic Woman Creek channel (see Figure 4.4-10). Pond C-1 has limited storage capacity and is used primarily for flow measurements. Pond C-2 does not receive flows from Woman Creek; an upgradient diversion structure redirects water from Woman Creek around the pond. Water re-entering Woman Creek below Pond C-2 was previously diverted into Mower Ditch and now flows into the Woman Creek Reservoir (part of the Standley Lake Protection Project).

Pond C-2 currently receives surface water from the South Interceptor Ditch, which intercepts surface runoff from the southern portion of the Industrial Area. Approximately 7,700 feet in length, the ditch parallels Woman Creek on the drainage's northern hillside. Surface water flow from OU1 (881 Hillside), OU2 (903 Pad), and OU5 (Woman Creek Drainage) is intercepted by the ditch and redirected into Pond C-2, where it is analyzed and treated (if necessary) prior to being discharged in accordance with the Site's NPDES permit.

The unnamed drainage to the south of Woman Creek historically was a tributary that joined Woman Creek immediately west of Indiana Street. During earlier agricultural activities in the southeastern portion of the Site, flows in this drainage (which are augmented by water from Rocky Flats Lake via Smart Ditch No. 1) were diverted away from Woman Creek toward the southeastern corner of the Site. This water flows through Ponds D-1 and D-2, which are not part of the Site runoff control or pollution prevention system.

Discharge from Terminal Ponds

Off-site discharges of water from the terminal ponds are currently conducted, during routine operations in a "batch release" mode. This means that flows in and out of an individual pond are temporarily terminated, thereby isolating the pond's water from the rest of the pond network. A sample of the isolated water is then collected and, if sample results indicate water quality standards and goals are met, the "batch" of water is pumped out of the pond or directly discharged to a stream that flows off the Site.

Prior to discharging Ponds A-4 and C-2, samples are taken and split for analysis between CDPHE and the Site contractor. In August 1993, all pre-discharge split samples collected for the Site analysis were performed at on-site laboratories for most analytes. At the beginning of October 1993, sample analysis performed by EPA-registered laboratories was replaced by analysis by the on-site general laboratories (located in Building 881) with the exception of pesticide and herbicide analyses. The change in laboratory use was mandated by budgetary considerations. Beginning in 1996, predischarge samples are still taken and split between CDPHE and the Site. However, the CDPHE samples are analyzed and the samples retained by the Site are analyzed only in event of a problem.

Discharges are monitored for parameters within the limitations of the NPDES permit limitations. In addition, water quality is tested before release to ensure that the water meets

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Colorado Water Quality Control Commission stream standards for Segment 4 of Big Dry Creek. Water is released with concurrence from CDPHE.

During discharge, samples are analyzed daily for Ponds A-4 and C-2 and are monitored for plutonium, americium, uranium, and tritium. Samples are analyzed daily for tritium, pH, gross alpha/beta, nitrate (as nitrogen), and nonvolatile suspended solids. Pond C-2 is sampled on a weekly basis four to six weeks prior to pond discharge; samples are sent to the on-site radiological health laboratory (located in Building 123). Weekly radiological monitoring of Pond A-4 prior to discharge was performed until November 1993, when monitoring was in response to CDPHE concerns for the quality of the water that was transferred from Pond B-5 to Pond A-4.

Plutonium, americium, and uranium samples are collected as daily composites for weekly analysis during all discharges from Ponds A-4 and C-2. Samples from Ponds A-4 and C-2 discharges are analyzed daily for tritium, pH, nitrate (as nitrogen), and nonvolatile suspended solids. Daily samples are collected in a similar manner at a sampling station on Walnut Creek near its intersection with Indiana Street. Chromium samples are analyzed monthly, and whole effluent toxicity samples are analyzed quarterly when discharge occurs at Ponds A-4, C-2, and transfer of Pond B-5.

Discharges from Pond A-4, which include transfers from Pond B-5, enter Walnut Creek and are diverted around Great Western Reservoir via the Broomfield Diversion Ditch. Discharges from Pond C-2 are pumped through an 8,000-foot pipeline into the Broomfield Diversion Ditch.

Pond treatment systems include filtration and granular activated carbon units at terminal Ponds A-4 and C-2. The Pond A-4 treatment system has a maximum treatment capacity of 1,200 gallons per minute and is located in a weatherproof enclosure to allow for cold weather operation. The Pond C-2 treatment system has a maximum treatment capacity of 750 gallons per minute and is not protected from the weather (it is generally not usable from November to March). Although granulated activated carbon units are the "best available technology" for removal of organic chemicals and some metals, and radionuclides are removed by particulate filtration, specific treatment capabilities for metals and radionuclides do not currently exist at either of these locations.

Discharges from Seeps

Seeps (springs) are common along the upper margins of the drainages. Seeps discharge ground water to surface water and soils at the Site. Because seeps potentially impact Site surface water quality and flow volumes, they are discussed in this section. The locations of seeps are shown in Figure 4.4-10.

Discharges from most seeps at the Site are not controlled. However, where there is the potential for contamination, seep discharges are monitored and in some cases treated. Currently, discharges from seeps in OU1 (881 Hillside), OU2 (903 Pad), and OU4 (Solar Evaporation Ponds) are treated prior to release. At OU1, ground water and infiltrate are collected via a French drain and treated to remove radionuclides, metals, and volatile organics. Treated effluent is released to two 150,000-gallon tanks for testing. The water is then released to the South Interceptor Ditch, which flows into Pond C-2. At OU2 (903 Pad), ground water from seeps is collected and piped to the OU2 field treatment unit and treated to remove radionuclides, metals, and volatile organics. By the end of 1994, nearly 25 million gallons of collected seep and surface water had been treated and released to South Walnut Creek (Kaiser-Hill 1995a). At OU4, discharge from seeps located immediately north of the Solar Evaporation Ponds is collected via a surface water ditch system that ultimately delivers the seep water to the OU4 Interceptor Trench System. The water is then pumped, stored, and treated as described in Section 4.3.4, "Environmental Restoration."

Flood Control

Flood problems along Colorado's Front Range are typically the result of convective storms, which are relatively short in duration but produce periods of high-intensity rainfall. These storms usually occur from May to September. There are 12 earthen dams at the Site, three of which were constructed with substantial flood storage capacities (these are for terminal ponds A-4, B-5, and C-2). See Figure 4.4-10 for the general location of the dams, which are situated along the A-, B-, C-, and D-Series detention ponds at the Site. The dams are subject to federal guidance for dam safety and Colorado state dam safety.

4.4.4 Surface Water Quality

This section describes Site surface water monitoring and quality issues related to compliance with National Pollutant Discharge Elimination System (NPDES) permitting standards, Colorado stream standards, and Department of Energy (DOE) radiological concentration guidelines for the discharge of surface waters from the Site. Surface water quality in nearby reservoirs is also described.

The basic goal of surface water management at the Site is to ensure that operations and activities are conducted to minimize impacts to human health and the environment while achieving and maintaining compliance with current regulations. Site surface water quality is managed through a series of interrelated programs—including weed control, vegetation stabilization, erosion control, monitoring, and pesticide control—delineated in the Site's *Watershed Management Plan*. Incidental surface water (e.g., water naturally collected in a depression or pond) is collected and treated under the Site's *Miscellaneous Sources Program Plan* to help maintain general surface water quality.

Background Surface Water Quality

An extensive site-wide surface water sampling program was conducted from 1989 to 1993 to evaluate potential contaminant releases and characterize background surface water quality. Additional analyses of the nature and extent of contamination in surface water continue to be conducted under the operable unit remedial investigation process. Background surface water quality has been characterized based on data collected from sampling locations in unimpacted areas of the Site. These locations are either upgradient or hydrologically disconnected from the Industrial Area. Surface water samples are compared statistically to background data to determine impacts to surface water quality due to Site operations.

While background comparisons do indicate impacts to surface water quality, surface water is released from the Site only upon assurance that all NPDES permitting standards have been met, and only with the concurrence of CDPHE (EG&G 1994b). Details are provided below.

Surface Water Monitoring

Surface water monitoring at the Site focuses primarily on Walnut Creek and Woman Creek drainages. Samples are routinely collected and analyzed from these drainages as well as from the Site's seeps and detention ponds. The Site monitors for radionuclides, organic chemicals, metals, and biological constituents in order to ensure compliance with specific regulatory requirements (EG&G 1994b) including RFCA. The list of parameters is similar to the list presented in Table 4.4-2 for ground water analyses.

Potential sources of influent contamination to the detention ponds include surface water and storm water flows, sediments contained in these flows, waste water treatment plant discharges, footing drain flows (e.g., from building drains), operable unit treatment discharges, ground water seepage, and new on-site spills. Programs have been implemented to control and monitor these potential sources of contamination. However, the historical impacts of these sources may still exist in the ponds in the form of contaminated sediments. Even when appropriate preventative measures have been taken, new spills, sediment transported by large storm events, and waste water treatment plant upsets may continue to be potential sources of contaminants into the Site ponds.

Prior to discharging water from the Site's terminal ponds (A-4, B-5, and C-2), samples are taken and split for analysis between CDPHE and the Site. Discharges are monitored to ensure compliance with the Site's NPDES permit. Parameters for which the terminal ponds are monitored include plutonium, americium, uranium, tritium, pH, gross alpha/beta, and total suspended solids. The ponds are sampled daily, weekly, or monthly depending on the chemical or parameter for which analyses are required.

The potential for contaminant transport in surface water is greatest during storm events and other periods of high flow. Storm water quality and/or quantity are measured with 20 stream gauging stations dispersed across the Site. The stream gauges, are equipped with continuously recording flow meters and automatic water samplers that are programmed to sample storm event and pond discharge event flows. The stream gauges assist in evaluating contaminant fate and transport across the Site. The existing surface monitoring stations have been evaluated through RFCA and the Site Data Quality Objective process. Three of the stations are for specific short-term projects and may be eliminated when they are no longer needed. The rest of the stations are intended for long-term monitoring of water quality and flow. Surface water sampling locations are shown in Figure 4.4-10.

Compliance With RFCA Surface Water Requirements

One of the objectives stated in the Preamble to the Rocky Flats Compliance Agreement was assurance of surface water protection. In this vein, protection of all surface water uses will be a basis for making interim soil and groundwater cleanup and management decisions. The quality of surface water leaving the Site during cleanup activities must meet standards for aquatic life, recreation, and agricultural classifications, and at the completion of cleanup activities, all surface water on-site and all surface and groundwater leaving the Site will be of acceptable quality for all uses, including domestic (drinking water) use.

In order to ensure realization of this objective, the RFCA excludes the site's existing NPDES permit from the agreement, and it provides that surface water be further protected through an Action Level Framework. This framework relies on monitoring performed at several surface water points of compliance which are located at the outfalls of terminal retention ponds. Further, the framework was developed so as to ensure that both action levels and remediation of groundwater, surface soil and subsurface soil were properly protective of surface water. Exceedance of action levels triggers evaluation, remedial action and/or management actions.

Compliance with NPDES Standards

The release of pollutants into United States waters is controlled by the NPDES permit program, which requires routine monitoring of chemical and biological constituents for point source discharges and reporting of results. Certain discharges must meet NPDES permit monitoring and compliance limitations. An updated renewal application has been submitted for the Site NPDES permit, which expired in 1989 and was extended administratively until renewed. In addition, the NPDES permit terms were modified by the NPDES Federal Facilities Compliance Agreement that was signed by DOE and EPA in March 1991. That agreement established additional monitoring requirements for the Site.

Chemical and biological constituents currently measured in surface water effluent samples are listed in Table 4.4-4. Concentrations are indicative of the overall quality of effluent discharges. No NPDES notices of violation were issued to the Site in 1994, 1995, or 1996.

Table 4.4-4 NPDES Permit Limits for Discharge of Site Surface Water under Baseline Conditions

Parameter[1]	NPDES Daily Maximum[2]	NPDES 7-Day Maximum Average[3]	NPDES 30-Day Maximum Average[3]	Maximum Measured Concentration
Discharge 001 (Pond B-3)				
Nitrate as N (mg/l)	N/A	20	10	7.3
Total Residual Chlorine (mg/l)	0.5	N/A	N/A	0.28
Discharge 002 (Pond A-3)				
pH (standard units)	9.0	N/A	N/A	8.2
Nitrate as N (mg/l)	20	N/A	10	3.5
Discharge 003 (Reverse Osmosis Pilot Plant)				
(No discharges during 1994)	N/A	N/A	N/A	No discharges
Discharge 004 (Reverse Osmosis Plant)				
(No discharges during 1994)	N/A	N/A	N/A	No discharges
Discharge 005 (Pond A-4)				
Total Chromium (µg/L)	50	N/A	N/A	<5.0
Discharge 006 (Pond B-5)				
Total Chromium (µg/L)	50	N/A	N/A	<4.0
Discharge 007 (Pond C-2)				
Total Chromium (µg/L)	50	N/A	N/A	No discharges
Discharge STP (Waste Water Treatment Plant)				
pH (standard units)	9.0	N/A	N/A	7.6
Total Suspended Solids (mg/l)	N/A	45	30	52.0
Oil and Grease (mg/l)	No Visual	N/A	N/A	N/A
Total Phosphorus (mg/l)	12	N/A	8	10.7
Total Chromium (µg/L)	100	N/A	50	8.5
Carbonaceous Biological Oxygen Demand 5-Day (mg/l)	25	N/A	10	13.2
Fecal Coliform (#/100 ml)[4]	N/A	400	200	530.0

[1]These are the NPDES permit limits as modified by the Federal Facilities Compliance Agreement effective April 1991. The agreement requires reporting but does not specify discharge limitations for many volatile organic compounds or metals.
[2]"Daily maximum" is the highest value during the month.
[3]The NPDES permit limits are specified as "monthly average" and "weekly average" and are measures of mean value for the shorter time periods as required by the permit.
[4]Fecal coliform averages calculated by geometric rather than normal mean.

RFCA requires that EPA issue a new NPDES permit within 6 months of the Colorado Water Quality Control Commission action. Interaction by the Site with EPA on the new NPDES permit has begun.

Compliance with Colorado Water Quality Stream Standards

In December of 1996, the Colorado Water Quality Control Commission (WQCC) agreed with the Site's proposal to change the Basic Standard in both surface and ground water for both americium and plutonium to 0.15 pCi/L from the current basic standard of 15 pCi/L. The WQCC agreed to delete unique tables for organic chemicals and the Site, under the Basic Standards tables, regulate making the Site consistent with other regulated waters.

Changed Rocky Flats specific surface water quality standards by the addition of temporary modifications for nitrate and nitrite from that of drinking water usage (10 mg/L) to an agricultural/aquatic life Class 2 standard (100 mg/L). Deletion of chloride, sulfate, iron, and manganese standards for surface water in segments 4 and 5.

The effective dates were bifurcated with the standards being effective for Woman Creek on March 3, 1997 and Walnut Creek on January 1, 1998 at the request of the City of Broomfield and the State of Colorado.

Water quality is also tested before release to compare with stream standards set by the WQCC. The WQCC established stringent stream standards for pond outlets and streams leading into the public water supplies of Great Western Reservoir and Standley Lake. DOE uses these standards as the primary guidance for general pond water management activities and discharge operations at the Site, although the standards are not included as official discharge effluent limitations under the 1994 NPDES permit. As noted above, water is released only with the concurrence of CDPHE. Standards are less stringent for tributaries leading into the detention ponds than out of them.

Although discharges from the terminal ponds meet the requirements of the NPDES permit, discharge water quality has in some instances exceeded WQCC stream standards for a few constituents. The few exceedances resulted from impacts of the waste water treatment plant effluent in conjunction with pond processes, which caused elevated concentrations of biological oxygen demand, fecal coliform, and total residual chlorine. Exceedances of the stream standards during the 1990s have included mean concentrations of gross beta, antimony, thallium, ammonia, cyanide, and sulfide (DOE 1994g).

Compliance with DOE Radiological Guidelines

Concentrations of plutonium, uranium, americium, and tritium in water samples from the outfalls of Ponds A-4, C-1, C-2 , and from Walnut Creek at Indiana Street are presented in Appendix G ("Water"). DOE's "derived concentration guides" for public waters are the applicable standard as prescribed by DOE under authority of the Atomic Energy Act. DOE Order 5400.5, "Radiation Protection of the Public and the Environment," delineates these standards. Surface effluent monitoring results demonstrate that the water concentrations are well below DOE's derived concentration guides (EG&G 1994b).

Concentrations of plutonium, uranium, americium, and tritium in water samples from the outfalls of Ponds A-4, C-1, and C-2 and from Walnut Creek at Indiana Street are listed in Table 4.4-5. DOE's "derived concentration guides" for public waters are the applicable standard as prescribed by DOE under authority of the Atomic Energy Act. DOE Order 5400.5, "Radiation Protection of the Public and the Environment," delineates these standards. Surface effluent monitoring results demonstrate that the concentrations are well below DOE's derived concentration guides. Mean concentrations of plutonium, uranium, americium, and tritium in water samples from the outfalls of Ponds A-4, C-1, and C-2 and from Walnut Creek at Indiana Street were less than 0.24% of applicable DOE derived concentration guides (EG&G 1994b).

Table 4.4-5 Maximum Measured Radiological Concentrations in Surface Water Effluent under Baseline Conditions

Analyte[1]	Pond A-4 (pCi/l)	Pond C-1 (pCi/l)	Pond C-2 (pCi/l)	Walnut Creek at Indiana Street (pCi/l)	Derived Concentration Guide (pCi/l)[2]
Plutonium 239/-240[3]	0.009 (± 0.007)	0.022 (± 0.008)	No discharges	0.024 (± 0.010)	30
Americium-241[4]	0.015 (± 0.007)	0.021 (± 0.016)	No discharges	0.023 (± 0.021)	30
Uranium-233/-234[5]	1.20 (± 0.160)	2.35 (± 0.260)	No discharges	1.52 (± 0.200)	500
Uranium-238[5]	1.40 (± 0.180)	1.63 (± 0.150)	No discharges	1.31 (± 0.180)	600
Tritium	297 (± 155)	340 (± 180)	No discharges	375 (± 174)	2,000,000

[1]Calculated as 1.96 standard deviations of the individual measurement (95% confidence interval).
[2]DOE derived concentration guides are based on the most restrictive assumptions for the gastrointestinal uptake fraction.
[3]Radiochemically determined as plutonium-239 and -240.
[4]Radiochemically determined as americium-241.
[5]Radiochemically determined as uranium-233, -234, and -238.

During 1993, the Site's raw water supply was obtained from Ralston Reservoir and from the South Boulder Diversion Canal. Ralston Reservoir water usually contains more natural uranium radioactivity that the water flowing from the South Boulder Diversion Canal. During the year, samples of the Site's raw water are analyzed for uranium, plutonium, americium, and tritium on a monthly basis.

Surface Water Quality in Nearby Reservoirs

Great Western Reservoir and Standley Lake are located downstream of the Site on the Walnut Creek and Woman Creek drainages, respectively. The reservoirs supply drinking water to the municipalities of Broomfield, Federal Heights, Westminster, Thornton, and Northglenn. Plutonium has been detected in sediments collected from these reservoirs, which are included as part of OU3 (Off-Site Releases). Mower Reservoir is located downstream of the Site along Woman Creek and is used for agricultural purposes.

Early operational practices at the Site included discharge of effluents containing metals, radionuclides, and inorganic ions into Walnut Creek and discharge of water treatment facility filter backwash into Woman Creek. A number of studies have addressed plutonium concentrations in bottom sediments at Great Western Reservoir and Standley Lake to determine impacts on these reservoirs from Site releases. Potential contaminant pathways examined have included air and water transport.

Maximum plutonium concentrations detected in sediments at Great Western Reservoir and Standley Lake in 1994 are 4.03 pCi/g and 0.553 pCi/g, respectively (DOE 1994d). The elevated plutonium concentrations in sediments at Great Western Reservoir are probably due to historical releases from the Site, while impacts on Standley Lake sediments from Site releases are uncertain. Many surface water samples have been collected and continue to be collected from these reservoirs.

Annual background samples were collected from Ralston, Dillon, and Boulder Reservoirs and from the South Boulder Diversion Canal at distances ranging from 1 to 60 miles from the Site. This monitoring program began in the early 1980s and was discontinued in October 1992. Samples were collected for background levels of plutonium, uranium, americium, and tritium. Concentrations of these constituents averaged 0.26% or less of the derived concentration guides established by DOE for protection of human health.

Background reservoir water quality data were compared with data from Standley Lake, Great Western Reservoir, and nine Denver-area community drinking water supplies (including Westminster and Broomfield). There were no substantial differences identified in radionuclide concentrations between these data sets. The data indicate that neither elevated radionuclide concentrations in sediments nor discharges from the Site impact drinking water supplies under baseline conditions (EG&G 1993l).

In addition to collecting surface water in detention ponds and analyzing it before discharge from the Site, other controls have been or are being implemented to protect downstream water supplies. In October 1990, DOE agreed to fund an off-site surface water supply project to further reduce any risks posed by the Site to downstream water users. The plan includes two primary components:

- Replacement of Great Western Reservoir as a drinking water supply for the City of Broomfield by the acquisition of an equivalent water supply (Carter Lake).
- Off-site improvements to protect Standley Lake water quality, including construction of Woman Creek Reservoir along Woman Creek just east of Indiana Street. Water discharged from Pond C-2 and water in Woman Creek flow into Woman Creek Reservoir. After testing, the water is transferred by pipeline to Walnut Creek below Great Western Reservoir, thereby bypassing Standley Lake altogether.

In general, the purpose of the off-site surface water supply project is to guard against potential accidental releases and not to serve as a remedial response. Although funding is provided by DOE, the Cities of Westminster and Broomfield have been responsible for designing and implementing the project. The Woman Creek Reservoir project was completed in 1996.

Water Quality Improvement Projects

Current projects related to water management activities to improve the quality of discharges from the Site are discussed below.

Outlet Works Upgrades

The outlet upgrade projects address concerns by the Colorado State Engineers Office, the Federal Energy Regulatory Commission, and the Army Corps Of Engineers that concrete pipes running under the terminal, as currently configured, are under continual pressure when water is held in the ponds. Valves installed on the end upstream of the outlet works, will relive pressure on the pipes when the valves are closed. Stand-pipes, or sediment-control structures, were added to the scope of the upstream gate valve project to allow continuous flow, or controlled detention, through the pond outlet works.

Installation of the upstream gate valve at Pond A-4 was completed on September 30, 1996. The upgrades allow direct discharges from Pond A-4 to north Walnut Creek through the improved outlet works. Outlet work upgrades for Ponds B-5 and C-2 are currently being planned for completion in March, 1998 and March, 2003. The initial review of the upgrade designs for Pond B-5 has been completed by the State Engineer's Office.

Wastewater Disinfection Process

The Site is replacing the current method of chlorination followed by dechlorination using sulfur dioxide with a new process that uses ultraviolet (UV) light to disinfect the final effluent. The new process will eliminate the need for the chlorine and sulfur dioxide pressurized gas systems.

Installation of the new disinfection process will, commence in March, 1997 and will be completed in approximately 3 months. Final conversion to the new process is expected to be completed on or about August 1, 1997 - three months ahead of schedule.

When the new system is in place the Site (WWTP) will no longer have the potential for releasing excess levels of chlorine through the plant outfall. The need to store and use chlorine and sulfur dioxide at the WWTP will be eliminated with the new process.

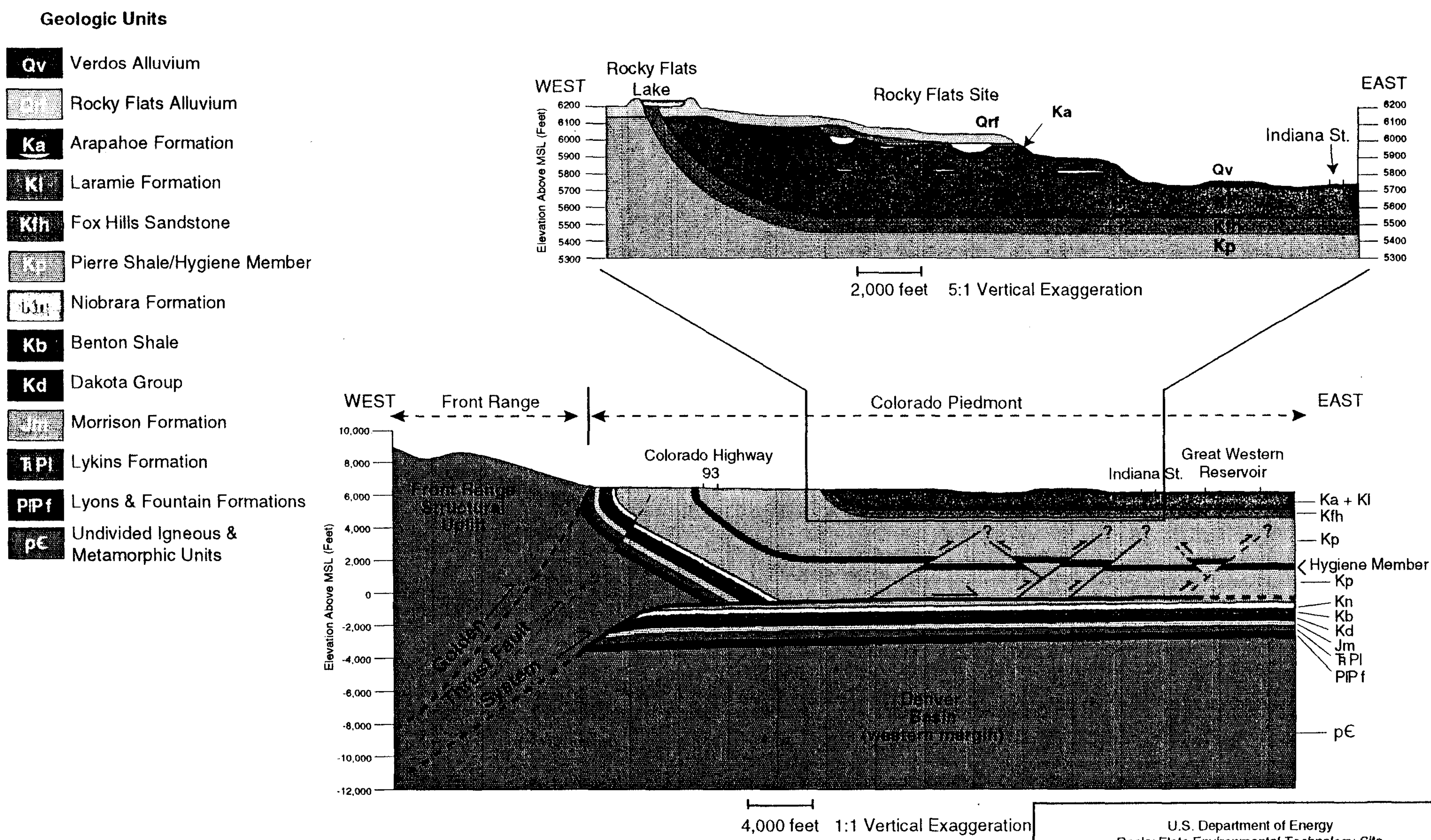
The Site has requested that once the new disinfection process is in-place, the NPDES requirement to monitor for Total Residual Chlorine be removed.

Wastewater Tanks

As an action item under the NPDES-Federal Facilities Compliance Act (FFCA), the Site is currently constructing influent and effluent tanks for the WWTP. The influent tank will have 3 cells and a storage capacity of 320,000 gallons, while the effluent tank will have 3 cells with a capacity of 550,000 gallons.

Major construction activities on the tanks are scheduled to be completed in July, 1997. Testing and final close-out of the tanks will be completed by September, 1997.

A detailed operational plan for the tanks is currently being developed. The tanks will be used to equalize the influent flows for better hydraulics and organic loadings on the plant. In the event of a spill empty influent tankage as well as effluent tanks will be used to hold suspect waters until the problem can be identified and a proper method of treatment can be determined.



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Golden, Colorado

Generalized Cross-Section of the Hydro-Stratigraphy Underlying the Site

Source: Kaiser-Hill 1995

Figure 4.4-1

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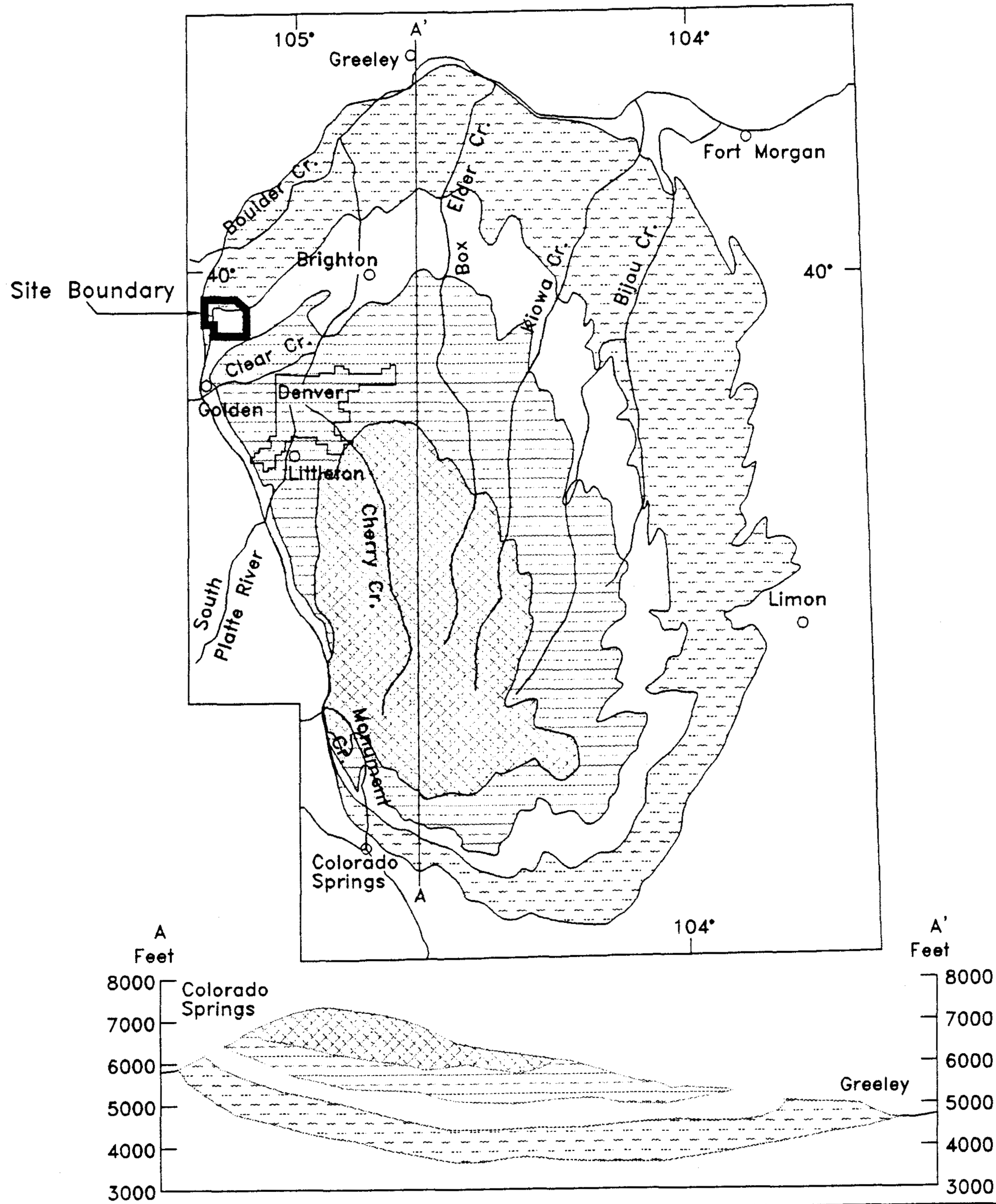

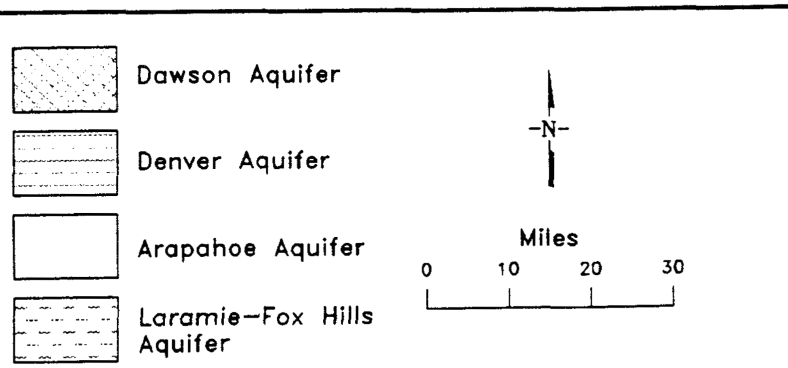

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Location and Extent of Bedrock Aquifers in the Denver Ground Water Basin

Source: Robson 1987

Figure 4.4–2

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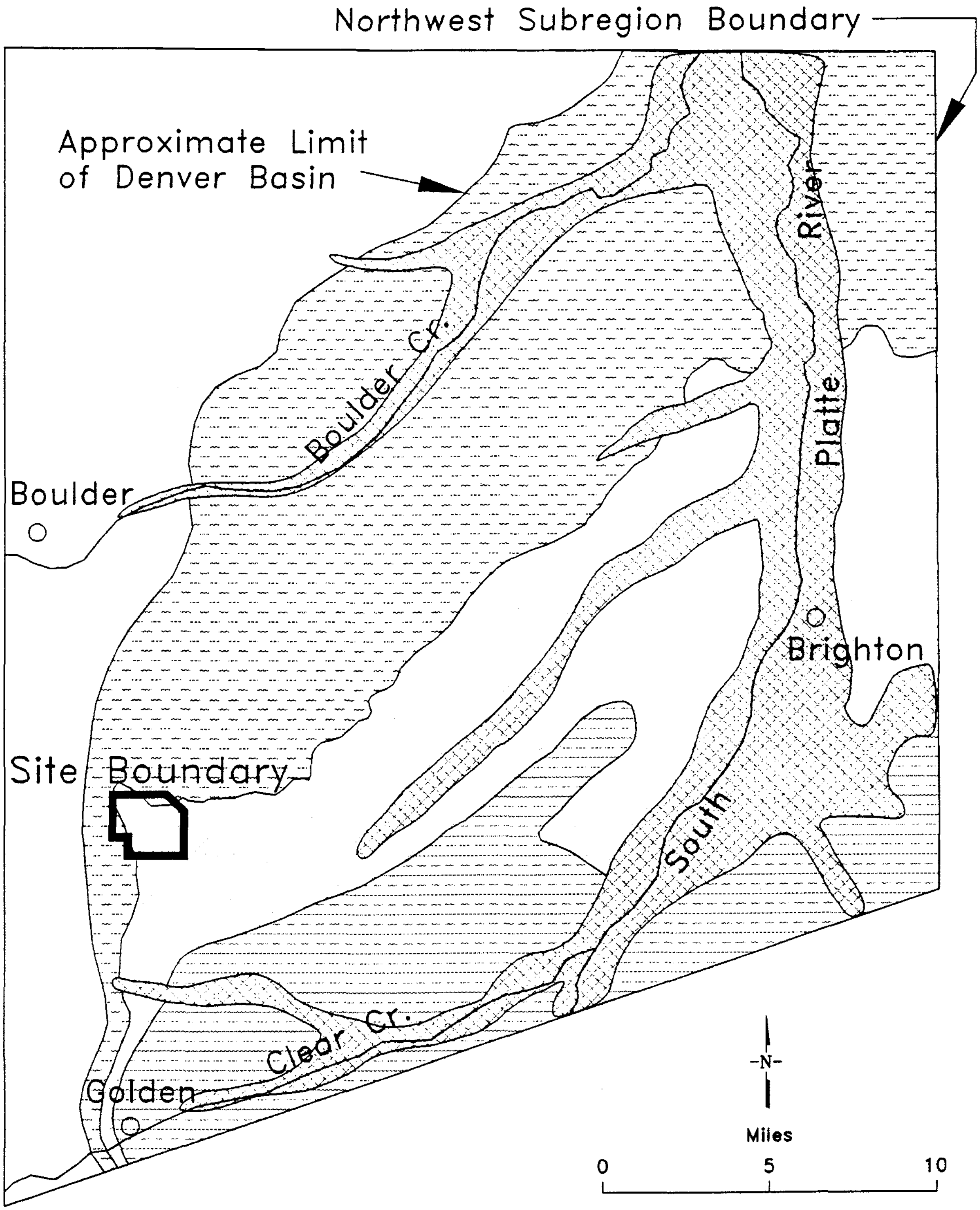

	Regional Alluvial Aquifer
	Denver Aquifer
	Arapahoe Aquifer
	Laramie–Fox Hills Aquifer

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Bedrock Alluvial Aquifer, Denver Ground Water Basin

Source: Robson 1981 and Robson 1987

Figure 4.4–3

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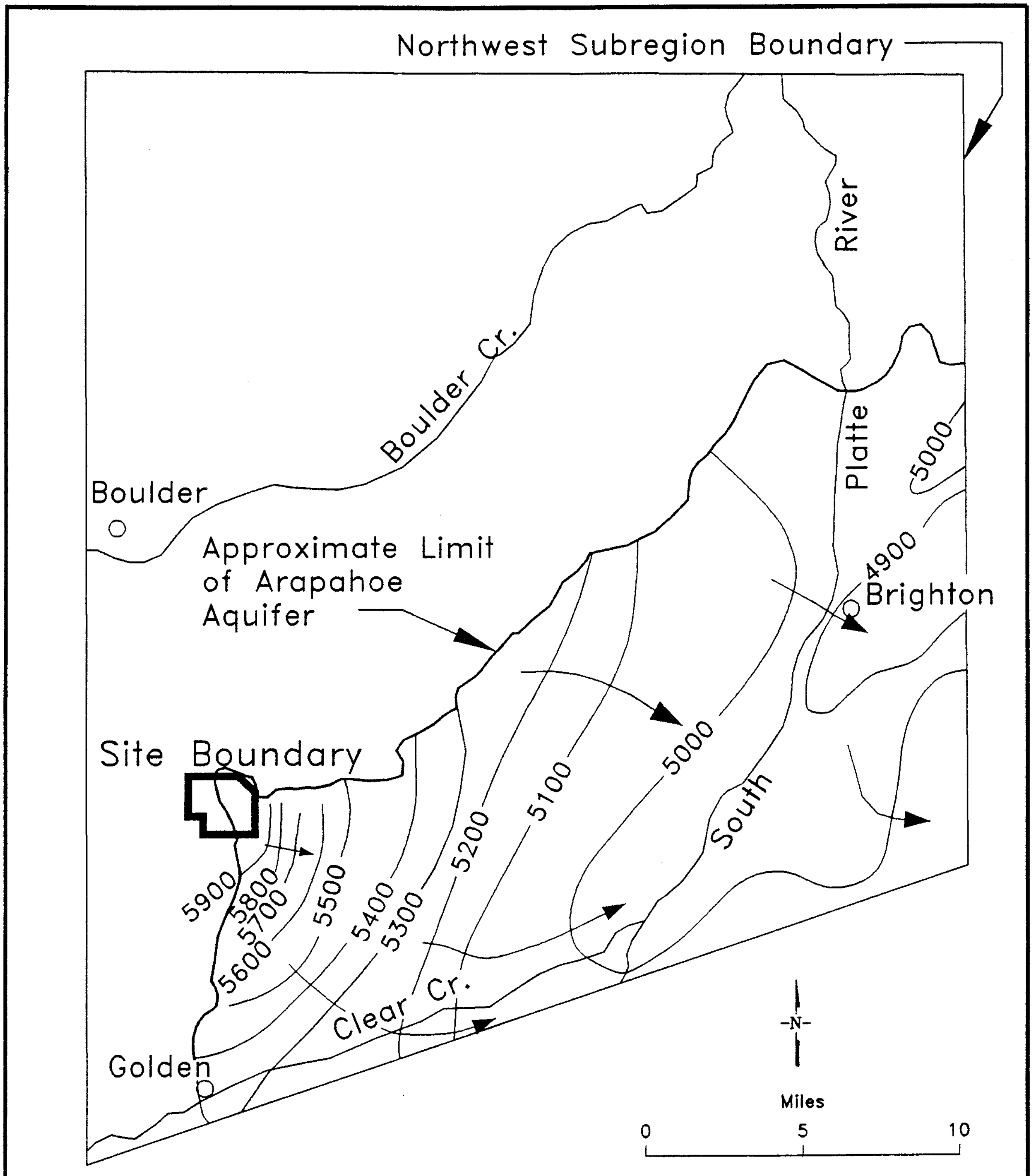

5000 Potentiometric Surface Contour and Groundwater Elevation (Nation Geodetic Vertical Datum of 1929) Contour Interval 100 feet

Approximate Direction of Groundwater Flow

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Arapahoe Aquifer,
Denver Ground Water Basin

Source: Modified from Robson et al 1981

Figure 4.4-4

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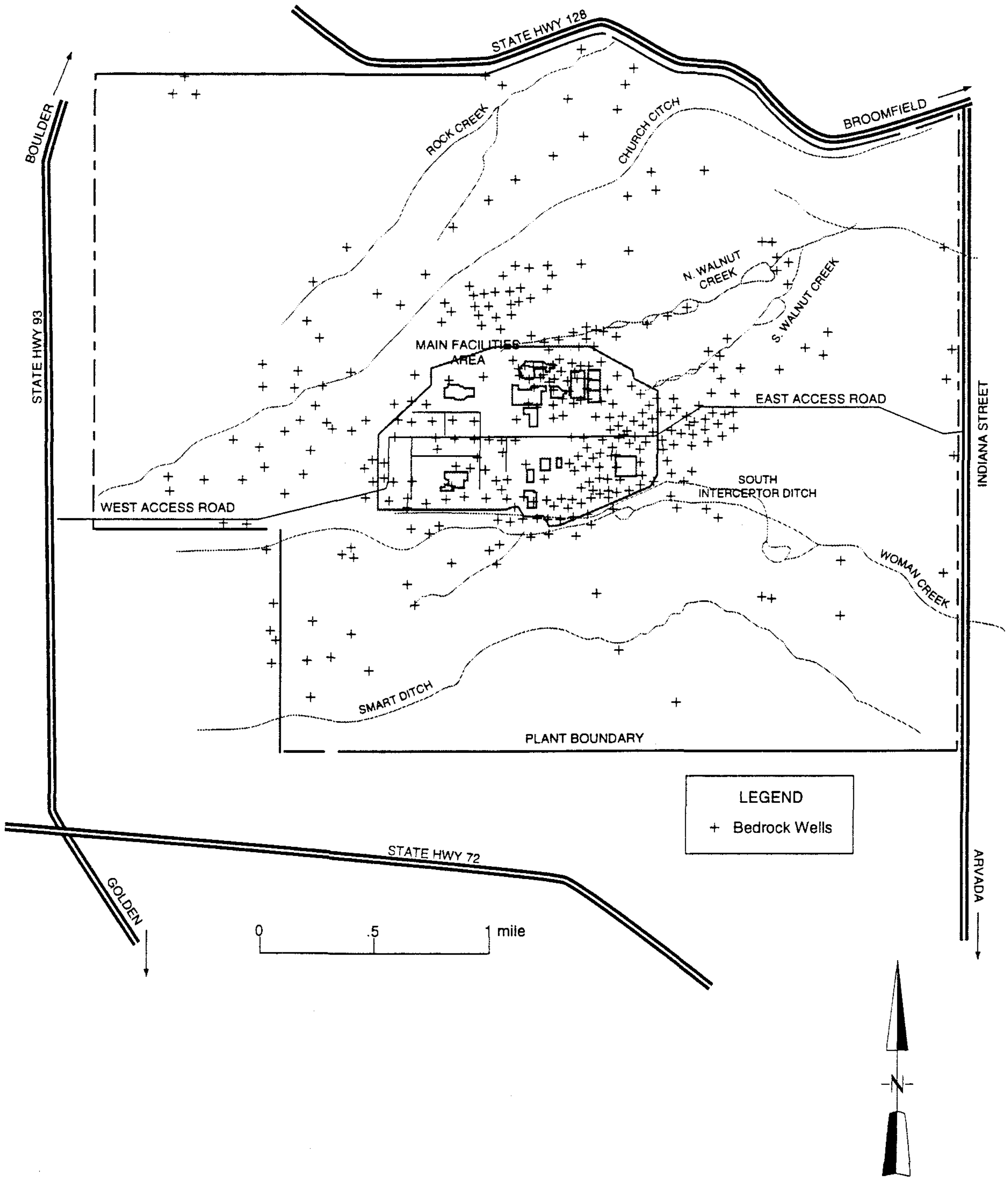

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Location of Monitoring Wells at the Site

Source: Kaiser-Hill 1995

Figure 4.4-6

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Monitoring Wells-3004.il

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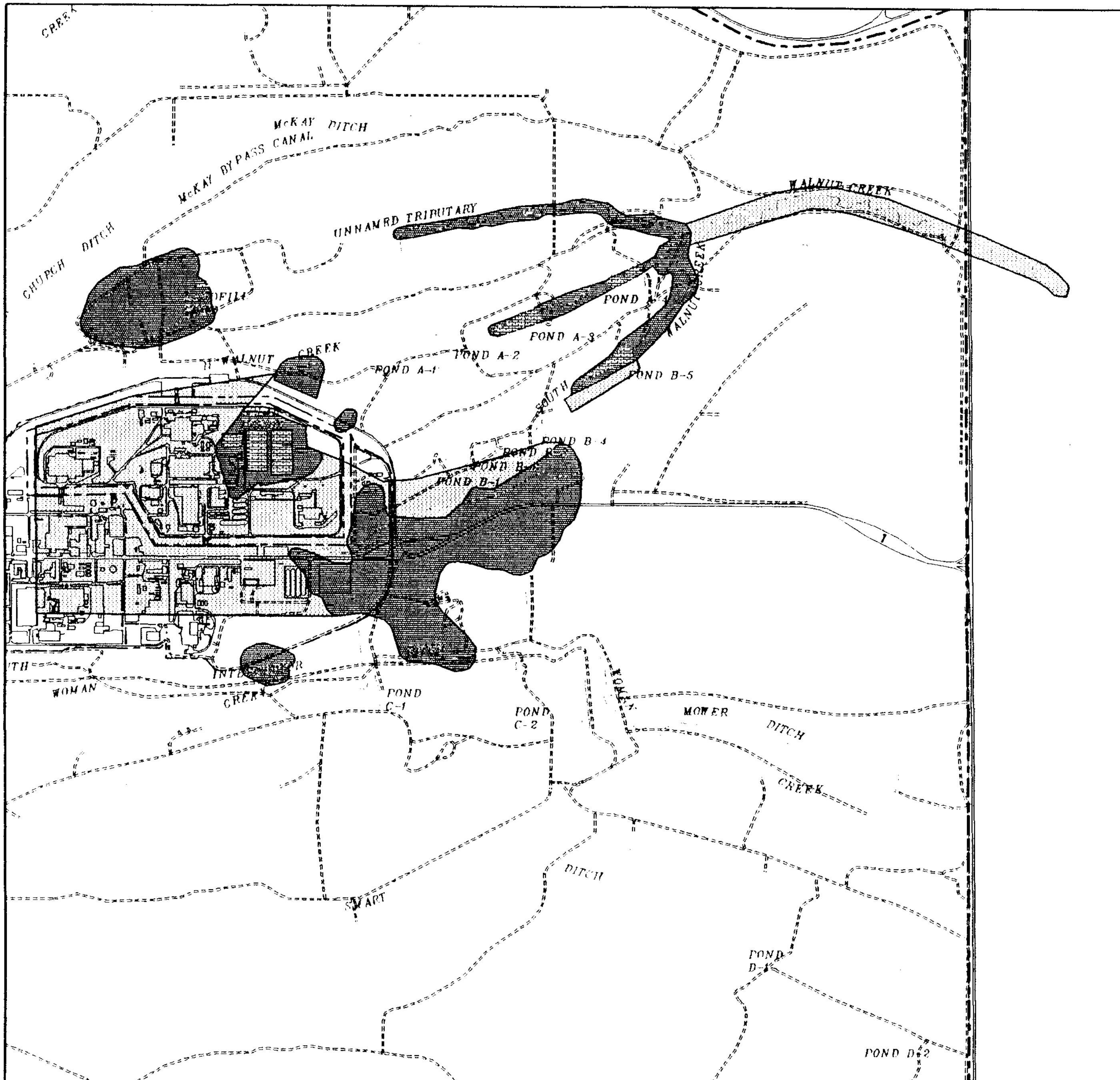

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Locations of Known or Suspected Ground Water Contamination Plumes at the Site

Source: Kaiser-Hill 1995

Figure 4.4-7

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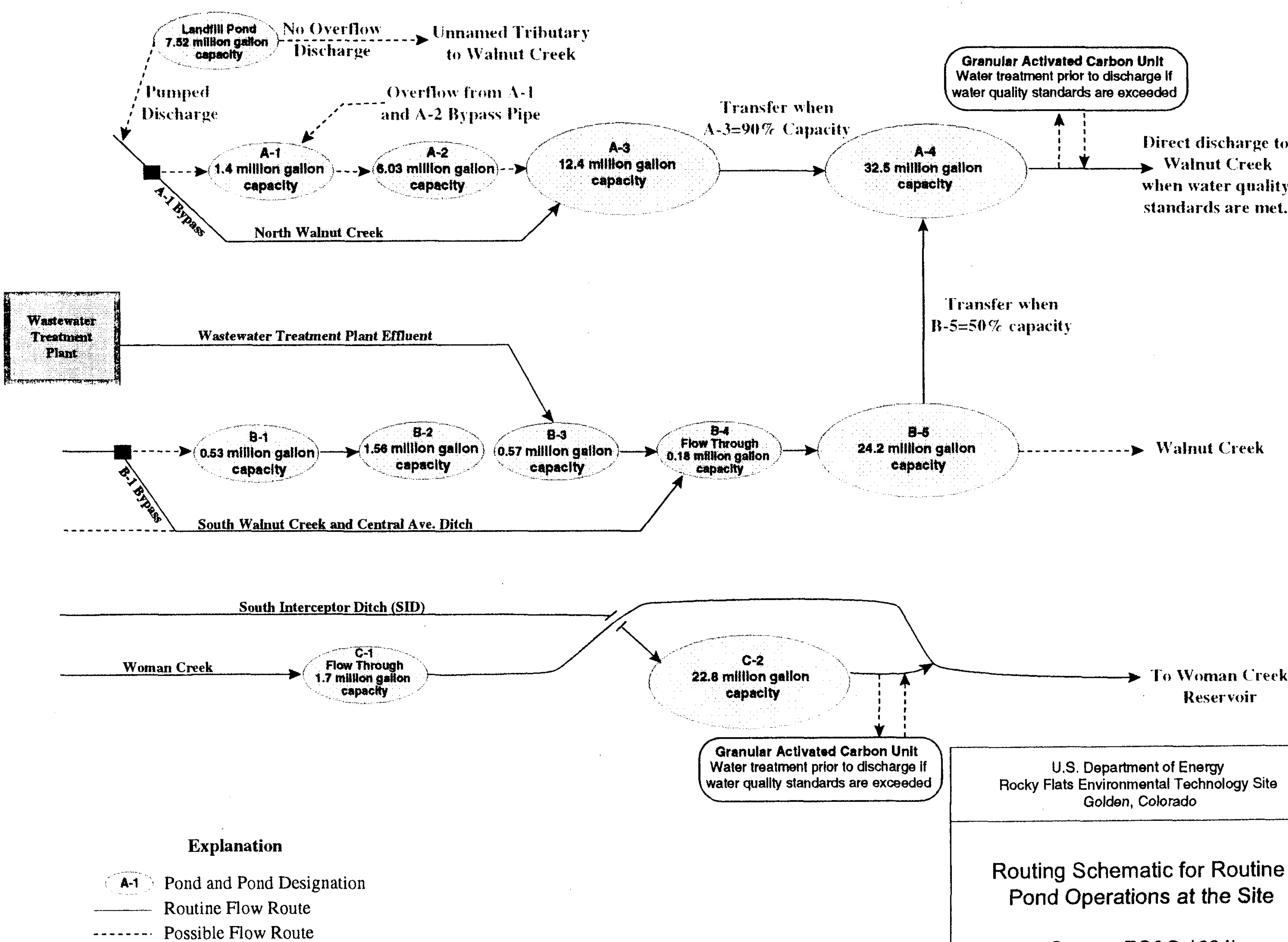

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Routing Schematic for Routine Pond Operations at the Site

Source: EG&G 1994b

Figure 4.4-9

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4.5 Air

Air monitoring programs have been implemented at the Site since the early 1950s (EG&G 1992b). The Site currently has air quality programs in place to protect workers, the general public, and the environment. The programs include monitoring and assessment of impacts on air from both radiological and nonradiological sources. Air quality management at the Site is implemented by the Site contractor's Air Quality organization.

Although production of nuclear materials at the Site ceased in November 1989, radioactive emissions from maintenance and support activities do occur. As discussed below, effluent radioactive air emissions are monitored continuously at 63 locations in 17 buildings. Ambient concentrations of radionuclides are also monitored on-site, at the Site boundary, and in surrounding communities.

Emissions of nonradioactive air pollutants are estimated and reported as part of the Site's compliance with applicable state and federal reporting and permitting requirements. CDPHE conducts ambient air quality monitoring at the Site boundary and in communities surrounding the Site as part of its state-wide ambient air quality monitoring network.

National Ambient Air Quality Standards have been established to protect public health and the environment for six "criteria" pollutants: carbon monoxide, sulfur dioxide, nitrogen dioxide, ozone, particulate matter less than 10 microns in size (PM-10), and lead. The Site is located within the boundary of the Denver Metropolitan Area for air quality planning purposes. This region is classified as "non-attainment" for carbon monoxide and PM-10, which means that ambient air quality in the area does not meet National Ambient Air Quality Standards. The Denver area is considered transitional for ozone and in attainment for the other criteria pollutants. A transitional classification means that the area was previously classified as non-attainment but is in the process of demonstrating attainment through continued ambient monitoring data and development of a regional plan to ensure attainment in the future.

This section begins with a description of general climatological conditions at the Site, followed by a description of baseline conditions for radiological and nonradiological air quality on-site, at the Site boundary, and in surrounding communities. Air quality is characterized on the basis of monitoring data, the Site's air emission inventory, and the results of air quality modeling of emissions.

4.5.1 Meteorology

The region has a continental, semi-arid climate characteristic of much of the southern Rocky Mountain region. This climate is characterized by large seasonal temperature variations and occasional dramatic short-term temperature changes.

Temperatures at the Site exhibit large diurnal and annual ranges but are generally moderate. Periods of extremely hot or cold weather are usually brief and may not occur every year. Average minimum and maximum temperatures based on 20-year means (for Boulder and Lakewood, Colorado) are approximately 19°F and 45°F in January and 59°F and 88°F in July (NOAA 1992). Temperatures as low as -25°F and as high as 105°F have been recorded at these monitoring locations. The mean annual temperature is 52.1°F for Boulder and 50.5°F for Lakewood.

Mean annual precipitation is approximately 15.5 inches, based on 20-year means for Boulder and Lakewood, Colorado (Kaiser-Hill 1995a). The wettest season is spring (March through

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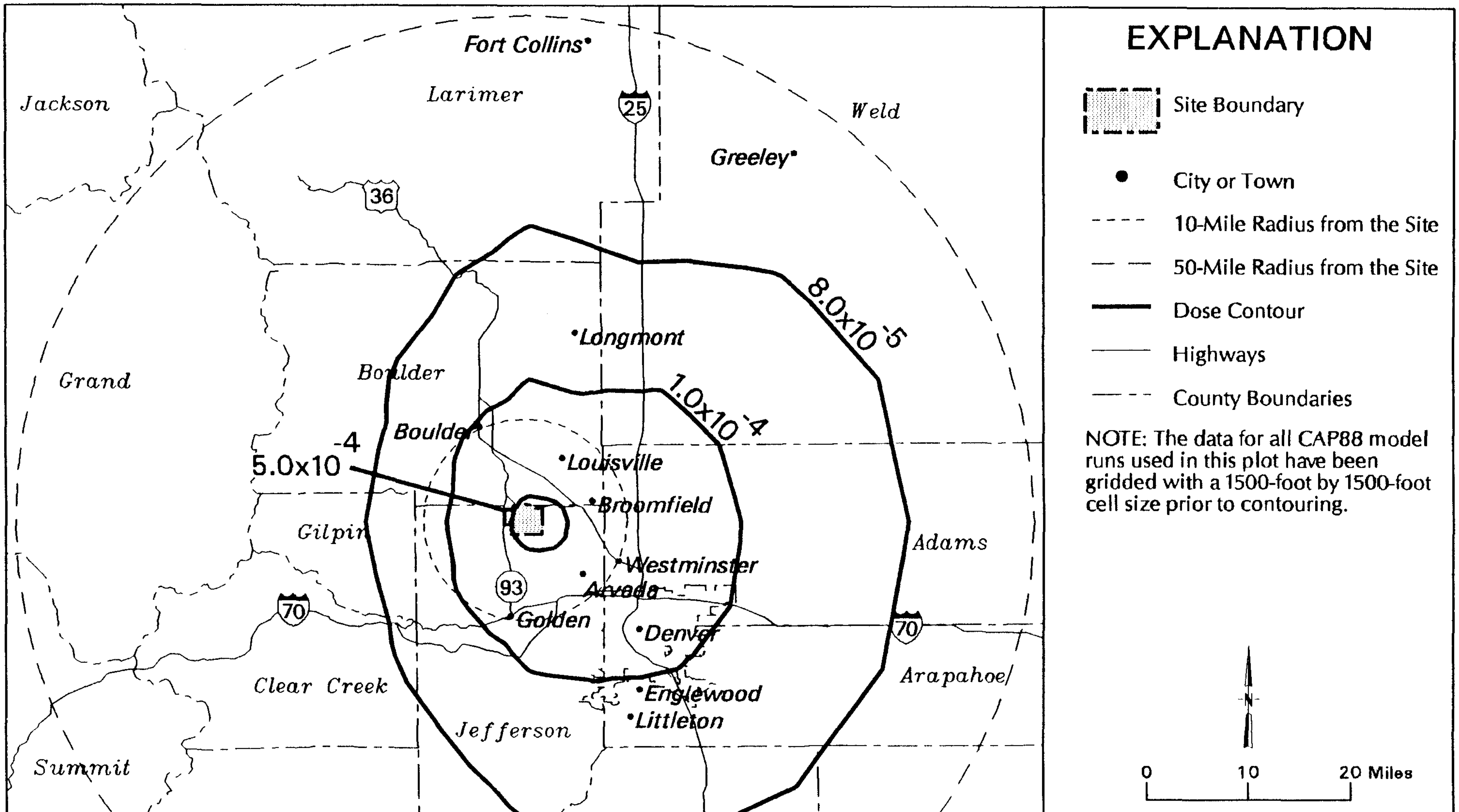
radiation to the nearest off-Site resident. Residents living further from the Site receive less additional radiation.

Site operations can result in release of radioactivity to the air either directly, through point sources such as stacks and vents, or indirectly from area sources such as the resuspension of radioactivity in contaminated soil. Concentrations of radionuclides in point-source releases are monitored or estimated based on knowledge of the materials used and activities performed. Area source releases are estimated by using calculations that relate contamination levels to expected airborne concentrations.

Radioactive emissions from Site point sources include small amounts of plutonium-238, -239, and -240; americium-241; uranium-233, -234, and -238; and tritium. Radiological emissions from area sources—principally contaminated soil—include plutonium-239 and -240, americium-241, and uranium-233, -234, -235, and -238. Area sources for selected plutonium isotopes (plutonium-238, -241, and -242) are not included because each contributes less than 10% of the total effective dose equivalent, and soil samples are not analyzed for these isotopes (see Section 4.8, "Human Health and Safety," for more information on total effective dose equivalent). Plutonium-239 and -240 constitute more than 97% of the alpha-emitting radioactive material used at the Site (DOE 1994i).

The Site is continuously monitored for direct radionuclide air emissions at 63 emission points in 17 buildings to ensure control of emissions and demonstrate compliance with National Emission Standards for Hazardous Air Pollutants (40 CFR 61, Subpart H). Because no routine nuclear weapons-related processing has occurred since November 1989, reported radionuclide point source emissions are believed to be primarily a result of resuspended residual radioactive material in the ventilation system (DOE 1994i).

Data from the *1993 Radionuclide Air Emissions Annual Report* (DOE 1994i) were used to develop the baseline radioactive air emissions at the Site. Data from the 1994 and 1995 *Radionuclide Air Emissions Annual Reports* (DOE 1995dd and DOE 1996m) are not significantly different from the 1993 data. All three years show less than 10^{-2} mrem per year effective dose equivalent to the nearest off-Site resident from air emissions only. For point sources, a scaling factor was applied to the 1993 emissions data to reflect work force reductions and limited waste management and special nuclear material operations. For area sources, estimated 1993 radionuclide air emissions resulting from the resuspension of past radioactive soil contamination were used for baseline conditions at the Site. The resuspension processes are discussed in detail in a report titled *Resuspension of Soil Particles from Rocky Flats Containing Plutonium Particulate* (Langer 1991). Annual quantities of radioactive materials from point and area sources are listed in Table 4.5-1. Radionuclide emissions are shown in curies. The curie is the standard unit for measuring radioactivity, defined as 3.7×10^{10} disintegrations per second.



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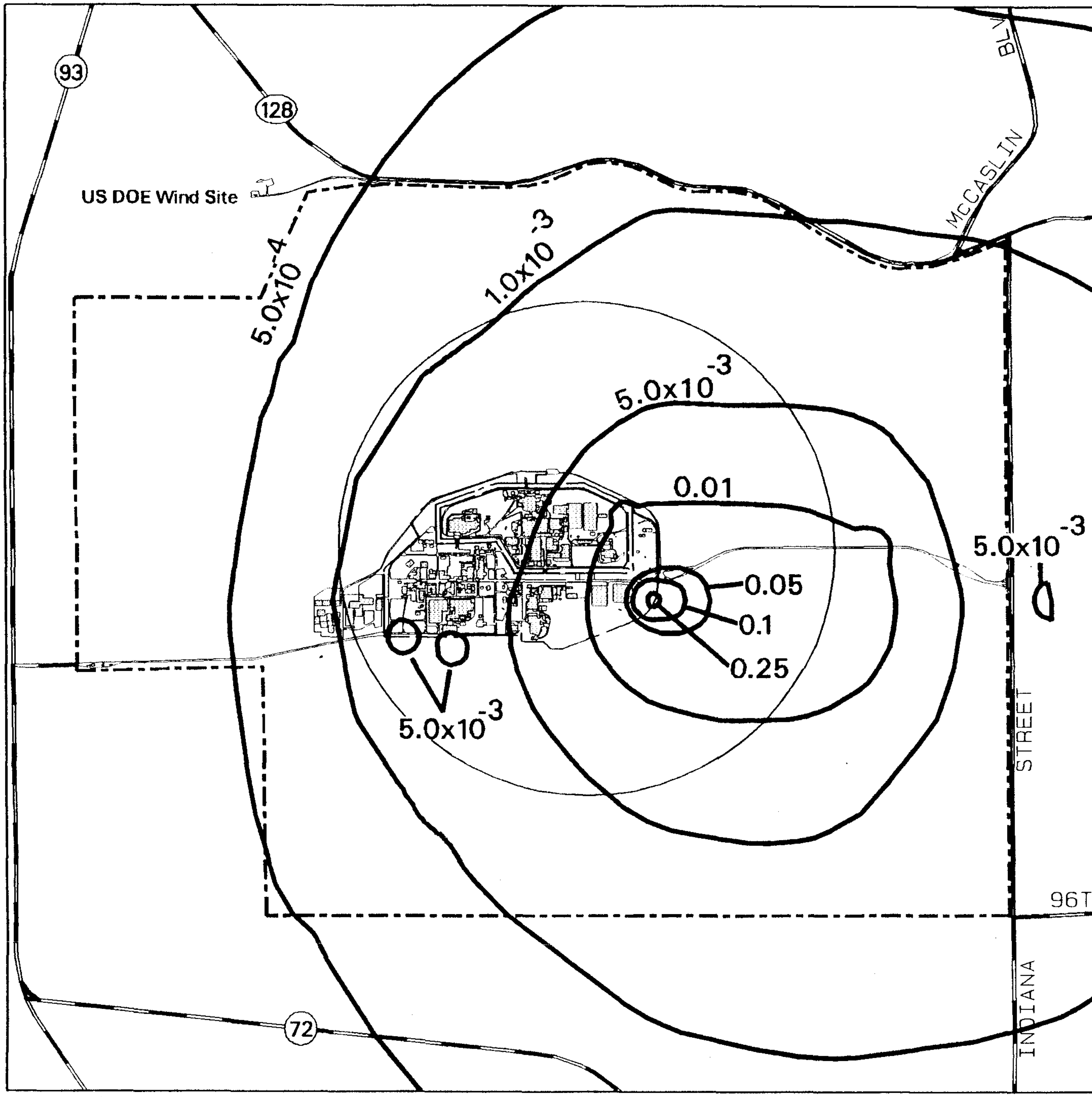
Estimated Radiation Dose - 50-Mile Radius
(millirem/year)

Figure 4.5-1

09-JUL-1996 GRA $DATA3/sweis/airrad/maps/radbasec.gra • AML /export/home/data3/sweis/airrad/amls/baseline/airradplot.aml



EXPLANATION

- Site Boundary
- Security Fence
- 1-Mile Radius from the Site
- Dose Contour
- Roads
- Buildings and Structures

NOTE: The data for all CAP88 model runs used in this plot have been gridded with a 100-foot by 100-foot cell size prior to contouring.

0 0.5 1 Miles

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Estimated Radiation Dose in Site Vicinity
(millirem/year)

Figure 4.5-2

09-JUL-1996 GRA $DATA3/sweis/airrad/maps/radbasef.gra • AML: /export/home/data3/sweis/airrad/amls/baseline/airradplot.aml

Table 4.5-2. Plutonium Sampling Results: Mean and Maximum Concentrations

Type	Location	Mean Concentration (x 10^{-15} mCi/ml)[1]	Percent of DOE Derived Concentration Guide[2]
On-Site	21 samplers	0.05566	0.278
Perimeter	14 samplers	0.00239	0.012
Community	11 samplers	0.00120	0.006
Type	**Location[3]**	**Maximum Concentration (x 10^{-15} mCi/ml)**	**Percent of DOE Derived Concentration Guide**
On-Site	S-8	0.84900	4.25
Perimeter	S-38	0.10900	0.55
Community	S-53	0.02100	0.11

Note: mCi/ml = microcurie(s) per milliliter.

[1]Most of the measured concentrations are at or very near background levels, and often there is little or no amount of material in the media analyzed.

[2]The DOE Derived Concentration Guide for inhalation of Class W Plutonium by members of the public is 20 x 10^{-15} mCi/ml. Protection standards for members of the public are applicable only for off-site locations.

[3]These designators refer to specific air sampler locations on-site, at the perimeter, and in surrounding communities.

Baseline Radiological Conditions

The radiological air emission estimates shown in Table 4.5-1 were used in the CAP88-PC dispersion model to estimate dose from Site operations under baseline conditions. Impacts were analyzed for the co-located worker, a maximally exposed off-site individual at the Site boundary, and the population within a 50-mile radius of the Site (collective dose). The estimated dose to these receptors under baseline conditions at the Site, together with the associated standards, are presented in Table 4.5-3. Results of the dispersion modeling analysis within 50 miles of the Site and in the immediate vicinity of the Site are also presented in Figures 4.5-1 and 4.5-2, respectively. A complete discussion of the dispersion modeling methodology for baseline radioactive air emissions at the Site is presented in Appendix B ("Human Health and Safety").

Table 4.5-3. Estimated Annual Radiological Dose for Baseline Conditions

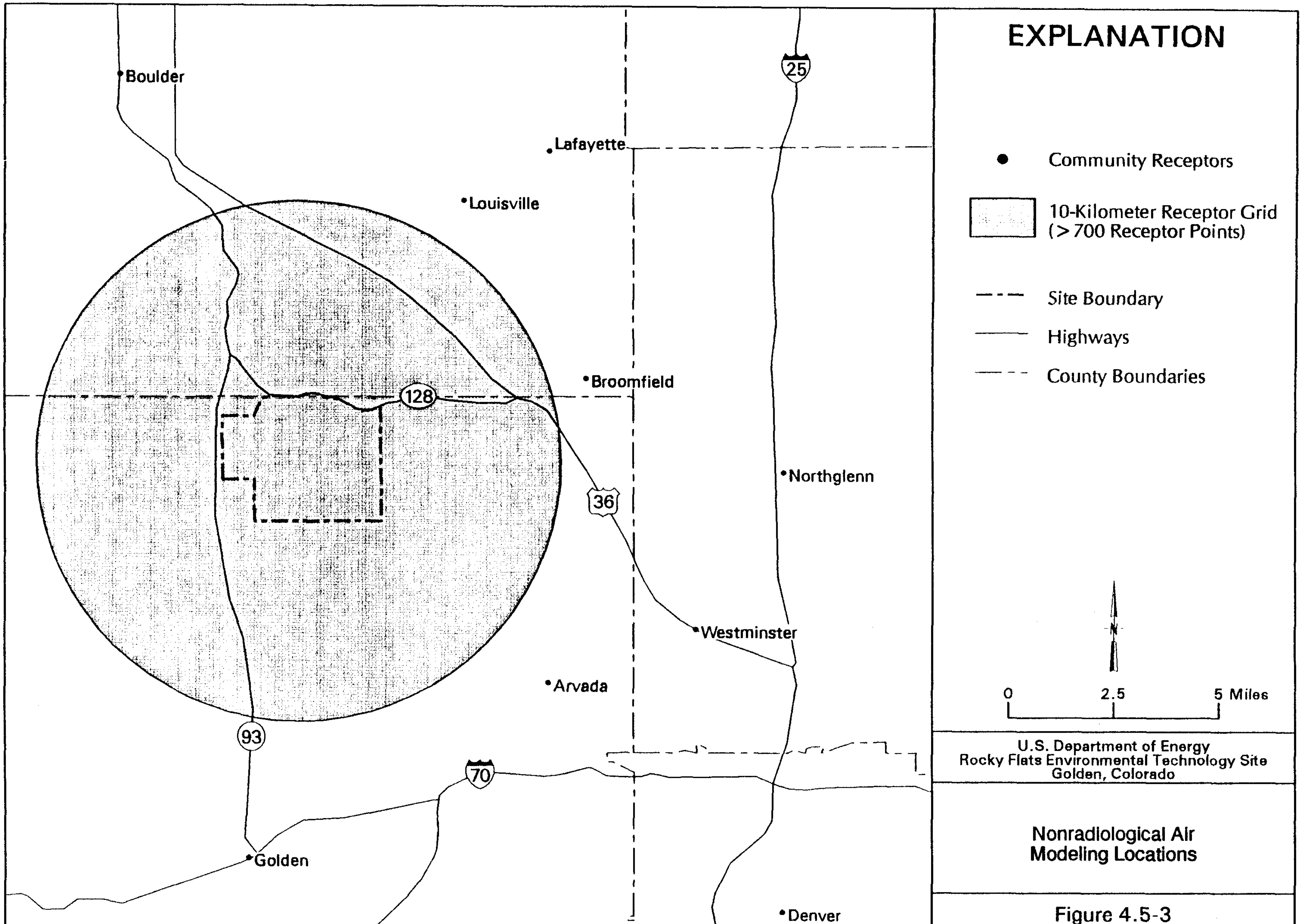
Receptor	Baseline Dose	Radiological Dose Standard
Co-Located Worker	0.29 millirem	5,000 millirem[1]
Maximally Exposed Individual	0.0052 millirem	10 millirem[2]
Population[3]	0.270 person-rem	–

[1]The radiological dose standard presented includes all exposure pathways. This standard is from DOE Order 5480.11, "Radiation Protection for Occupational Workers."

[2]This standard is from 40 CFR 61, Subpart H ("National Emission Standards for Hazardous Air Pollutants")

[3]Collective dose to an estimated population of 2.2 million people within 50 miles of the Site.

A more detailed description of worker and public health and safety, and the relationship of airborne exposures to other exposure pathways, is presented in Section 4.8, "Human Health and Safety."



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Nonradiological Air Modeling Locations

Figure 4.5-3

21-JUN-1996 GRA: $DATA3/sweis/airrad/maps/nonradc.gra • AML: /home/data3/sweis/airrad/amls/baseline/nonradplot.aml

4.5.3 Nonradiological Air Quality

Activities at the Site involve the use of combustion equipment, such as steam boilers and emergency power generators, and many types of chemical compounds that could release air pollutants to the atmosphere. Residents of the Denver Metropolitan Area are exposed to small quantities of these pollutants through off-site transport. These residents are also exposed to pollutants emitted from agricultural activities, industrial activities, automobile emissions, windblown dust from street sanding operations, and emissions from residential woodburning. In this section, sources of nonradiological air emissions from the Site are identified and the concentrations of pollutants to which workers on-site and individuals off-site are exposed are summarized and compared to federal and state standards or guidelines designed to protect human health.

Emissions from the Site

Pollutants emitted as a result of Site operations that were considered in this analysis include both "criteria" pollutants, for which National Ambient Air Quality Standards have been established, and non-criteria reportable pollutants with potentially toxic properties, called hazardous air pollutants. There are six criteria pollutants: carbon monoxide, sulfur dioxide, nitrogen dioxide, ozone, particulate matter less than 10 microns in diameter (PM-10), and lead. Total suspended particulate (TSP) matter is also designated as a criteria pollutant by the State of Colorado. Ozone, one of the criteria pollutants, was not specifically addressed in this analysis because it is formed in the atmosphere far downwind of emission sources and is usually analyzed on a regional basis. In addition, organic compounds, among the precursors of ozone in the atmosphere, are emitted from Site activities in quantities below State of Colorado major source threshold limits.

Hazardous air pollutants addressed include both chemicals identified by EPA as potential carcinogens, such as carbon tetrachloride, and non-carcinogenic health hazards, such as ammonia, nitric acid, and hydrochloric acid. The term hazardous air pollutants includes hazardous air pollutants listed in Section 112 of the Clean Air Act and other non-criteria reportable pollutants listed by the State of Colorado.

Point sources of air pollution emissions at the Site include combustion sources such as boilers and emergency generators, which emit primarily criteria pollutants, and laboratories and waste management operations, which emit primarily hazardous pollutants. An emissions inventory of all emissions sources operating at the Site was compiled for 1994. Sources no longer in operation as of June 1996 were removed from the 1994 Site emission inventory. This revised source list was then used to reflect nonradiological baseline conditions at the Site.

Because Colorado has developed reporting requirements for all sources of criteria and hazardous air pollutants, reports compiled for the state were used to determine pollutants to be considered in the analysis. The criteria pollutants emitted from individual sources in quantities greater than the Colorado emissions reporting threshold were modeled to determine on-site and off-site concentrations. Hazardous pollutants emitted in quantities greater than the most stringent State of Colorado reporting thresholds, as determined on a site-wide basis, were also modeled to determine both on-site and off-site concentrations.

Eighteen air pollutants were emitted in quantities greater than the State of Colorado reporting thresholds under baseline conditions. The Site's annual and maximum hourly emission rates for these pollutants are listed in Table 4.5-4.

Table 4.5-4. Annual and Maximum Hourly Emission Rates of Air Pollutants for Baseline Conditions at the Site

Pollutant	Site Annual Average Emissions	Site Maximum Hourly Emissions
	tons per year	pounds per hour
Criteria Pollutants		
Carbon Monoxide	41.0	191
Lead	1.7×10^{-12}	1.7×10^{-12}
Nitrogen Dioxide	172	861
Particulate Matter (PM-10)[1]	12.5	97.7
Sulfur Dioxide	11.2	532
Total Suspended Particulates (TSP)[1]	13.2	106
Hazardous Pollutants		
Ammonia[2]	0.71	0.71
Beryllium[2]	3.8×10^{-6}	3.8×10^{-6}
Carbon Tetrachloride	0.18	0.09
Chlorine	0.11	0.03
Chloroform[2]	0.36	0.36
Dioctyl Phthalate[2]	0.01	0.01
Hydrochloric Acid	0.27	0.17
Hydrofluoric Acid	0.10	0.05
Hydrogen Sulfide	1.06	0.26
Methylene Chloride	0.47	0.37
Nitric Acid	2.11	1.14
1,1,1-Trichloroethane	1.21	4.94

[1]PM-10 and TSP emissions are presented for information purposes only and were not used to model on-site or off-site concentrations of these pollutants. See "Monitored Pollutant Levels" section below.

[2]Maximum hourly emissions (lb/hr) were calculated by adjusting the annual average emissions (tons/yr) by the number of operating hours per year from multiple paint sources. For example, 1.0 tons/yr x 2,000 lb/ton divided by 2,000 hrs/yr (i.e., 40 hrs/week x 50 weeks/yr) is equal to 1.0 lb/hr.

Maximum hourly emission rates are based on actual design capacity of the unit or process operation. The annual emission rates reported for the Site are either the maximum reported emissions or CDPHE's maximum permitted emission rates. It should be noted that actual emission rates are lower. Conservatively, the maximum emission rates were used in the dispersion modeling analysis described below in this section.

Monitored Pollutant Levels

Nonradioactive ambient air monitoring is performed by the Site contractor near the eastern edge of the Industrial Area and provides information for on-site particulate levels. CDPHE also operates monitoring stations around the Site perimeter for PM-10 and TSP, volatile organic compounds, nitrogen oxides, and beryllium. Maximum concentrations of PM-10 and TSP recorded at the CDPHE stations were considered as the ambient off-site concentrations of these two criteria pollutants. These sampling locations are predominantly downwind of the Site and are thus representative of Site impacts. Because of the lack of definitive emissions data for the fugitive sources of PM-10 and TSP, this approach was determined to be the most accurate representation for the ambient concentrations of these pollutants. On-site concentrations of TSP and PM-10 were determined by using the recorded concentrations from two on-site PM-10 and TSP samplers located on the east side of the Industrial Area. These samplers are operated on a six-day sampling frequency to monitor both point source and fugitive dust impacts from Site operations.

With the exception of data for PM-10 and TSP, insufficient monitoring data exist for the other criteria and hazardous pollutants to adequately characterize baseline ambient air quality conditions. Therefore, characterization of ambient air quality for the other pollutants was based on atmospheric dispersion modeling of criteria and hazardous air pollutant emissions. The modeling procedures and assumptions used for this purpose follow those recommended and approved by both EPA and CDPHE for regulatory compliance purposes.

EPA's Industrial Source Complex-2 model was used to predict ambient concentrations of criteria and hazardous pollutants on-site and off-site. The five most recent years of representative meteorological data (1989-1993) were used. The maximum potential impact of Site emissions at receptors in the foothills west of the facility (considered complex terrain) were determined using EPA's SCREEN2 model in its complex terrain mode.

Pollutant concentrations were estimated for a total of 782 on-site and 758 off-site receptors. A map of the off-site receptor points is provided in Figure 4.5-3. The remainder of this section describes on-site and off-site baseline air quality conditions.

On-Site Conditions

On-site pollutant concentrations were estimated at 782 receptor locations by modeling emissions from all Site sources. Estimated 8-hour levels of both criteria and hazardous air pollutants were compared to occupational exposure limits set by Occupational Safety and Health Administration (OSHA) or the American Conference of Government Industrial Hygienists. Results of the on-site modeling process are presented in Table 4.5-5. For emissions of the maximum permitted levels of criteria and hazardous pollutants, the estimated concentrations of each pollutant are all well below the most restrictive occupational exposure limit.

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Table 4.5-5. Highest Predicted 8-Hour Concentration of Criteria and Hazardous Air Pollutants at On-Site Locations for Baseline Conditions at the Site

Pollutant	Site Maximum 8-Hour Concentration ($\mu g/m^3$)[1]	8-Hour Occupational Exposure Limit ($\mu g/m^3$)[2]	Percentage of Limit or Standard
Criteria Pollutants			
Carbon Monoxide	5,005	40,000	13
Lead	1.7×10^{-10}	50	< 1
Nitrogen Dioxide[3]	2,424	5,600	43
PM-10[4]	90.8	5,000	2
Sulfur Dioxide	2,308	5,000	46
TSP[4]	157.5	15,000	1
Hazardous Pollutants			
Ammonia	35.8	17,000	< 1
Beryllium	4.0×10^{-3}	2.0	< 1
Carbon Tetrachloride	9.3	12,600	< 1
Chlorine	12.3	1,500	< 1
Chloroform	5.6	9,780	< 1
Dioctyl Phthalate	0.7	5,000	< 1
Hydrochloric Acid	5.1	7,000	< 1
Hydrofluoric Acid	2.6	2,500	< 1
Hydrogen Sulfide	98.0	14,000	< 1
Methylene Chloride	9.5	1,765,000	< 1
Nitric Acid	33.4	5,000	< 1
1,1,1-Trichloroethane	3,657	1,900,000	< 1

[1]The values presented are the highest 8-hour concentrations estimated by the ISC-2 model for on-site receptors.
[2]All occupational exposure limits represent OSHA standards.
[3]It was assumed that 20% of oxides of nitrogen emissions from stacks are nitrogen dioxide. This is a conservative assumption based on the fact that less than 10% of the nitrogen oxide emissions from combustion sources at the stack exit are in the form of nitrogen dioxide.
[4]PM-10 and TSP emissions were not modeled. It was assumed that PM-10 and TSP concentrations obtained from on-site co-located monitors are representative of on-site conditions. Data represent 24-hour maximum concentrations from the *1993 Site Environmental Monitoring Report* that were adjusted to reflect 8-hour concentrations using a persistence factor of 1.75 (EPA 1988).

Off-Site Conditions

Off-site concentrations were estimated at 758 receptor locations radiating from the Site in all directions to a distance of 22 miles. These receptors included 36 locations along the boundary of the Site and 10 locations in nearby towns. The highest off-site criteria pollutant concentrations under baseline conditions were all below National Ambient Air Quality Standards and State of Colorado standards, as shown in Table 4.5-6. All maximum concentrations for criteria pollutants were detected at receptors at or near the Site boundary. Total concentrations include the maximum Site concentrations, ambient background concentrations, and maximum concentrations from other nearby sources. Comparing the total concentration of nonradiological pollutants to the air standards provides a conservative estimate of air quality impacts.

Table 4.5-6. Highest Predicted Off-Site Concentrations of Criteria Pollutants for Baseline Conditions

Pollutant	Average Time	Site Concentration ($\mu g/m^3$)	Total Concentration ($\mu g/m^3$)	NAAQS ($\mu g/m^3$)[1]	State Ambient Standards ($\mu g/m^3$)[2]	% of NAAQS	% of State Standard
Carbon Monoxide	1-hour 8-hour	1159.2 303.8	14,873 4,301	40,000 10,000	– –	37 43	– –
Lead[3]	Monthly	4.8×10^{-14}	4.8×10^{-14}	1.5	1.5	< 1	< 1
Nitrogen Dioxide[4]	Annual	1.4	21.2	100	–	21	–
PM-10[5]	24-hour Annual	– –	32.0 14.0	150 50	– –	21 28	– –
Sulfur Dioxide	3-hour 24-hour Annual	269.5 91.2 0.1	448.0 137.3 10.8	1,300 365 80	700 – –	34 38 14	64 – –
TSP[5]	24-hour Annual	– –	73.0 31.0	– –	260 75	– –	28 41

[1]NAAQS are National Ambient Air Quality Standards.

[2]State ambient standards are Colorado State Ambient Air Quality Standards.

[3]Ambient lead concentrations were predicted on a monthly basis because of averaging time limitations in the ISC-2 model. The monthly lead concentrations are conservatively compared to the quarterly NAAQS of 1.5 $\mu g/m^3$.

[4]It was conservatively assumed that 100% of oxides of nitrogen emissions from stacks are nitrogen dioxide. Although only a small percentage of nitrogen oxide emissions are in the form of nitrogen dioxide, oxides of nitrogen convert to nitrogen dioxide over time in the atmosphere.

[5]PM-10 and TSP concentrations were obtained from CDPHE's nearby ambient PM-10 and TSP monitors located along the eastern boundary of the Site.

Because ambient standards for hazardous air pollutants have not been developed by the State of Colorado, standards and guidelines from 12 states were compiled and used to develop conservative recommended values for the pollutants associated with Site activities. The estimated off-site levels of hazardous air pollutants from Site activities were then compared with these recommended values. Off-site concentrations of hazardous air pollutants were all below the recommended values, as shown in Table 4.5-7.

Table 4.5-7. Highest Predicted Off-Site Concentrations of Hazardous Air Pollutants for Baseline Conditions

Pollutant	Average Time	Site Concentration ($\mu g/m^3$)	Total Concentration ($\mu g/m^3$)[1]	Recommended Values ($\mu g/m^3$)[2]	Percentage of Recommended Values
Ammonia	1-hour	7.06	7.06	1,800	< 1
	8-hour	1.57	1.57	170	< 1
	24-hour	0.56	0.56	4.73	12
	Annual	8.8×10^{-3}	8.8×10^{-3}	4.73	< 1
Beryllium	1-hour	4.6×10^{-4}	4.6×10^{-4}	0.05	< 1
	8-hour	5.8×10^{-5}	5.8×10^{-5}	0.01	< 1
	24-hour	1.9×10^{-5}	1.9×10^{-5}	0.001	2
	Annual	6.0×10^{-8}	6.0×10^{-8}	0.0004	< 1
Carbon Tetrachloride	1-hour	1.46	9.27	1,300	< 1
	8-hour	0.25	1.45	300	< 1
	24-hour	0.09	0.49	74.4	< 1
	Annual	2.4×10^{-3}	0.010	0.07	14
Chlorine	1-hour	4.42	8.36	300	3
	8-hour	0.55	1.15	15	8
	24-hour	0.18	0.38	3.6	11
	Annual	2.4×10^{-3}	6.3×10^{-3}	0.4	2
Chloroform	1-hour	3.59	3.59	980	< 1
	8-hour	0.86	0.86	250	< 1
	24-hour	0.27	0.27	117.6	< 1
	Annual	2.9×10^{-3}	2.9×10^{-3}	0.04	7
Dioctyl Phthalate	1-hour	0.32	0.32	1,200	< 1
	8-hour	0.06	0.06	–	–
	24-hour	0.02	0.02	–	–
	Annual	2.0×10^{-4}	2.0×10^{-4}	12	< 1
Hydrochloric Acid	1-hour	2.81	5.02	150	3
	8-hour	0.35	0.69	75	< 1
	24-hour	0.13	0.24	2.03	12
	Annual	3.1×10^{-3}	5.3×10^{-3}	2.03	< 1
Hydrofluoric Acid	1-hour	1.02	1.02	26	4
	8-hour	0.14	0.14	26	< 1
	24-hour	0.05	0.06	0.68	8
	Annual	1.3×10^{-3}	1.3×10^{-3}	0.34	< 1
Hydrogen Sulfide[3]	1-hour	35.39	35.39	142	25
	8-hour	4.42	4.43	140	3
	24-hour	1.47	1.48	3.79	39
	Annual	0.02	0.02	0.9	2
Methylene Chloride	1-hour	2.17	2.19	260	< 1
	8-hour	0.50	0.50	1,740	< 1
	24-hour	0.16	0.16	417.6	< 1
	Annual	3.9×10^{-3}	4.2×10^{-3}	2	< 1
Nitric Acid	1-hour	21.70	22.06	500	4
	8-hour	3.02	3.07	100	3
	24-hour	1.11	1.13	50	2
	Annual	0.03	0.03	0.12	24
1,1,1,-Trichloroethane	1-hour	414	414	190,000	< 1
	8-hour	52.1	52.1	38,000	< 1
	24-hour	17.4	17.4	1,040	2
	Annual	0.02	0.02	1,000	< 1

[1]The values presented are the highest total concentrations estimated by the ISC-2 model for off-site locations from Site impacts and other nearby sources.

[2]Recommended values are air quality guidelines, values or standards for hazardous pollutants developed by different states.

[3]The State of Colorado 1-hour ambient standard for hydrogen sulfide of 142 $\mu g/m^3$ was used as a recommended value.

A complex terrain screening model was used to determine concentrations of pollutants at elevated receptors west of the Site. Air quality impacts from Site emissions on elevated terrain receptors are well below appropriate standards and recommended values. Thus, a more refined modeling analysis for complex terrain was not warranted. A detailed description of the complex terrain modeling analysis and results are presented in Appendix B ("Human Health and Safety").

Summary of Nonradiological Air Quality

Nonradiological air quality emissions from the Site were estimated at numerous locations on-site and off-site to determine baseline air quality conditions. All estimated levels of criteria and hazardous pollutants were below applicable federal and state standards and guidelines. Potential health risks associated with nonradiological air emissions from the Site are described in Section 4.8, "Human Health and Safety."

4.6 Traffic and Transportation

Movement of people and materials to and from the Site is an activity with potential associated impacts. The purpose of this section is to describe and quantify the transportation activities that occur at and around the Site and on transport routes for materials being shipped to other sites under baseline conditions. This description sets the stage for analyzing traffic and transportation impacts in Chapter 5, "Environmental Consequences." Local and on-site traffic are described, followed by a description of materials transportation.

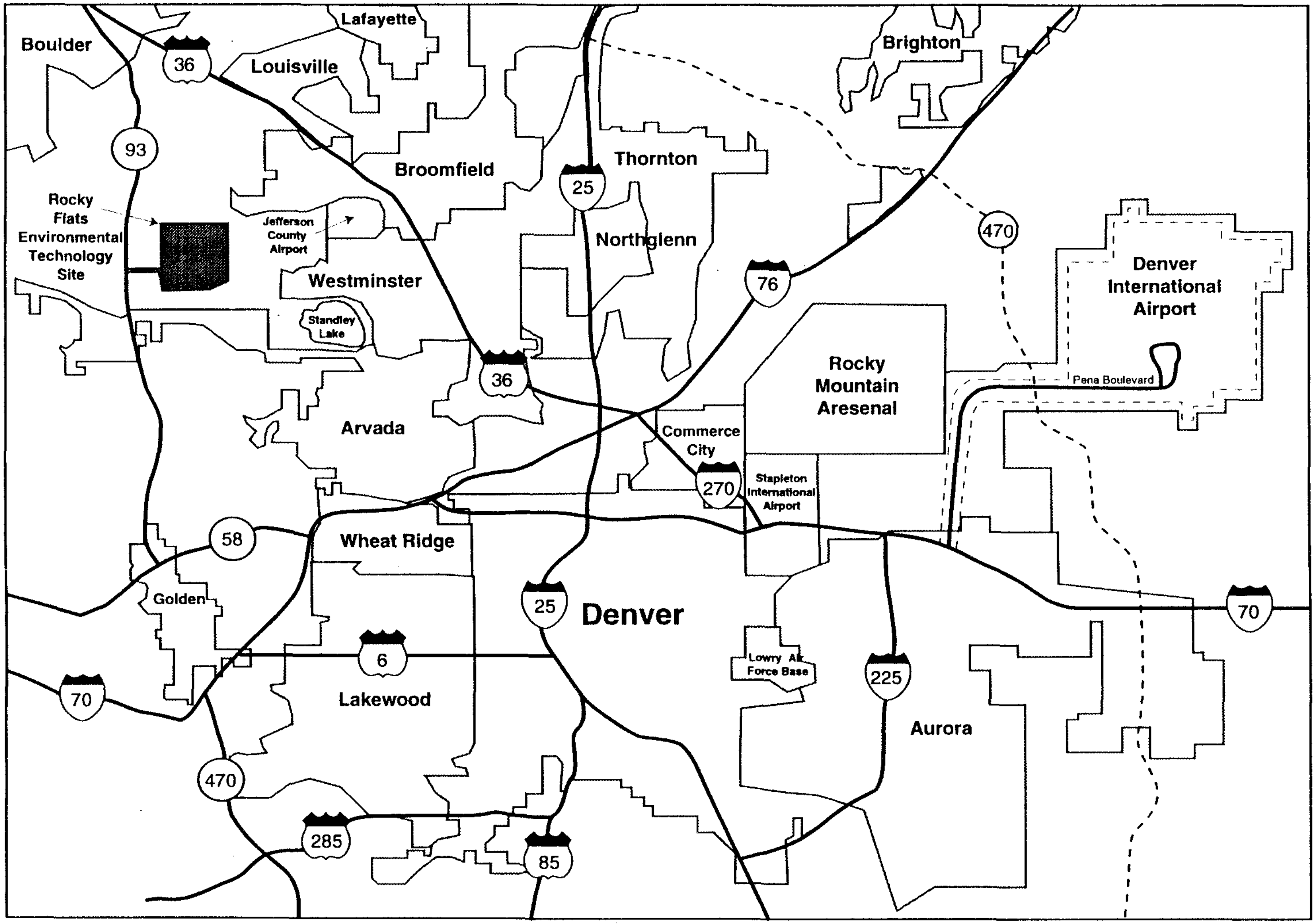
Local and On-Site Traffic

The Site is located in the western Denver metropolitan region, which is served by three major thoroughfares: U.S. Highway 36 (also called the Boulder-Denver Turnpike), Interstate Highway 25, and Interstate Highway 70. Traffic in the immediate vicinity of the Site is borne by four local highways: State Highways 72, 93, and 128 and Jefferson County Highway 17 (also known as Indiana Street). Access to the Site is available from State Highway 93 on the west via the West Access Road or from Indiana Street on the east via the East Access Road. Both access roads have automated access gates (and security check stations that can be activated if the need arises) within a few hundred yards of the intersection of the access road and the local highway. Figure 4.6-1 shows major transportation routes in the Denver region. Figure 4.6-2 depicts roads near the Site.

Rail freight service to the Site is provided by a spur of the Southern Pacific Lines railroad which is planning to merge with Union Pacific. The spur ends within the Site boundary and does not serve any other customers except Western Aggregate. Commercial air service to the Denver region is provided through Denver International Airport, which is located approximately 40 miles east of the Site. The Jefferson County Airport is 5 miles east of the Site and serves private and other small aircraft.

On-site, roadways for routine traffic with the Industrial Area are paved, maintained in good condition, and required to be free of obstructions. The speed limit on the east and west access road is 50 miles per hour. Roadways have posted speed limits, yield signs, and stop signs. Within the Industrial Area, posted speed limits generally vary from 10 to 25 miles per hour. The entire roadway system within the Industrial Area is lighted from dusk to early morning. The Site has approximately 143 miles of paved roads and 64 miles of unpaved roads.

Local traffic resulting from Site activities includes both cargo-related and local commuter travel. Cargo-related traffic includes primarily shipments of nonhazardous materials such as supplies and construction materials and hazardous materials such as flammable gases and bulk chemicals to the Site, and shipment of waste off-site to local commercial facilities. Mileage from these shipments is estimated at 5,000 miles per year. Local commuter travel consists primarily of private vehicle traffic by employees and contractor personnel. No public transportation system provides service to the Site, but a voluntary van-pool system is available and the RTD bus stops at the West Access road.



Map not to scale

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Golden, Colorado

Major Transportation Routes in the Denver Region

Figure 4.6-1

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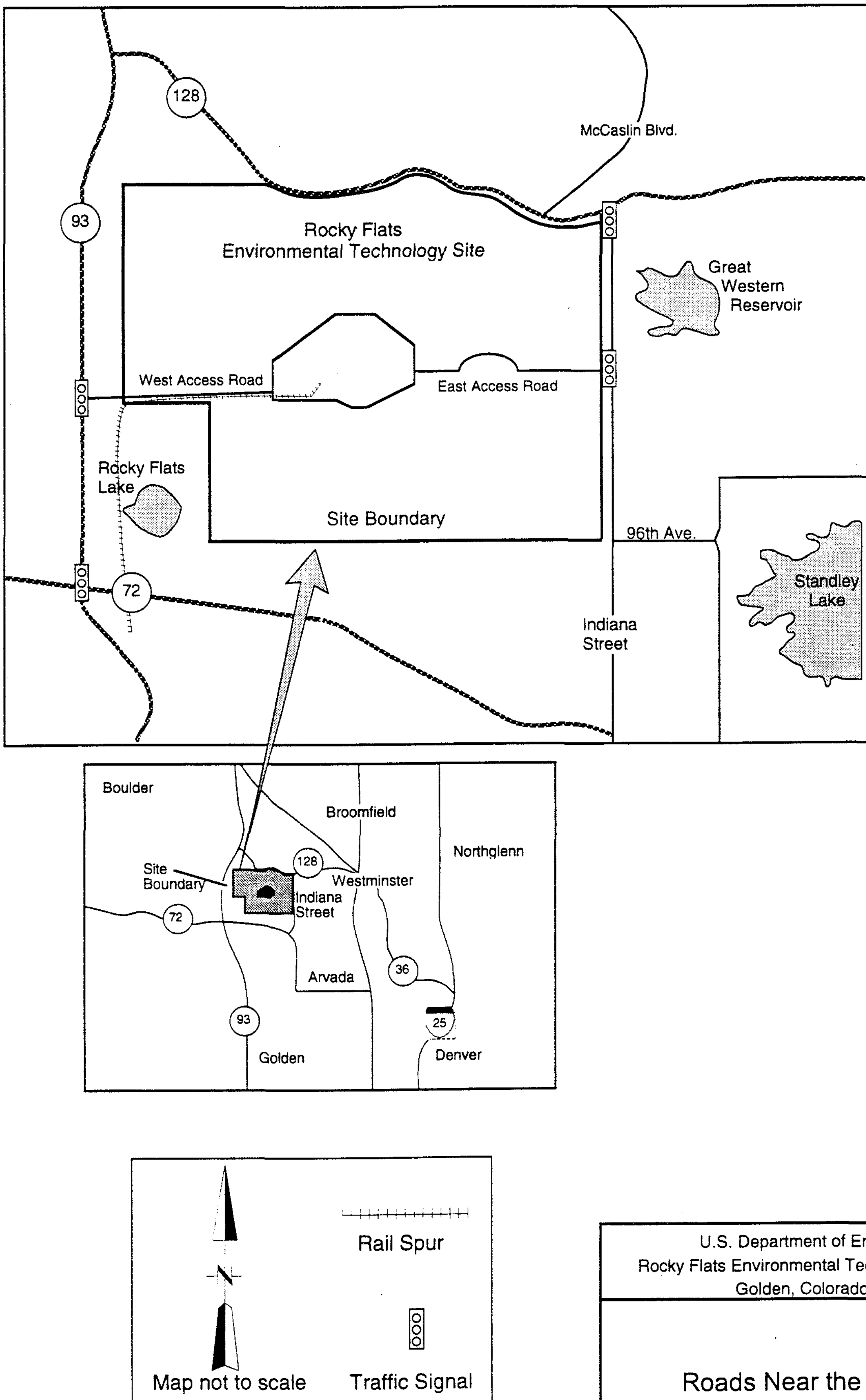

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Roads Near the Site

Figure 4.6-2

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G95\ES\SWEIS\RFP Map-3004

Data from 1991 (EG&G 1992e), along with baseline Site population figures, were used to estimate traffic levels under baseline conditions. This results in a conservative estimate since the 1996 Site population is approximately one-half the 1991 population. Commuter travel, which is the largest contributor to traffic and traffic impacts, is estimated at approximately 78 million miles per year under baseline conditions. Under baseline conditions, maximum daily averages of 6,539 personal vehicles and 13 commercial vehicles were estimated. This level of daily traffic has little effect on local traffic congestion except during brief periods around shift changes.

Upon arrival at the Site, employees and contractors typically leave their private vehicles at one of the designated parking lots. On-site transportation is generally provided by government or company vehicles, as well as by private vehicles when travel is necessary between buildings. Bicycles are available at numerous locations and are used by individuals to travel between buildings and areas at the Site. However, most on-site travel is predominantly pedestrian.

A variety of vehicles ranging from motorcycles and automobiles to heavy-duty diesel-powered vehicles is used on-site. On-site traffic consists principally of protective force vehicles, contractor and employee personal vehicles, Site contractor/government work vehicles, commercial delivery vehicles, and miscellaneous contractor vehicles. Although private vehicles driven by employees and contractors commuting to the Site represent the largest number of on-site vehicles, most of the on-site mileage is accumulated by government vehicles, especially protective force vehicles. Since there is no record of personal vehicle usage on-site, on-site government vehicle usage figures from 1991 were used to develop an annual mileage estimate of 1.9 million miles under baseline conditions (EG&G 1992e).

Very few serious transportation accidents have occurred at the Site, and no accidents have been severe enough to result in a release of radioactive or hazardous materials to the environment that would endanger the health or safety of employees or the general public. Typical transportation accidents involved damage to personal vehicles; personal injury in these cases was usually minor. However, protective force vehicles involved in transportation accidents have often sustained above-average damage, as the vehicles may have been responding to an emergency or been engaged in a training exercise involving above-average speeds. A few personal vehicle accidents have resulted in serious injury and one vehicle-jogger fatality. In the serious personal injury cases cited, high rates of speed, falling asleep while driving, or unknown circumstances were the primary reasons indicated as causes for the accidents. All but one of these serious accidents took place on Site access roads or within 1 mile of the Site.

Table 4.6-1 reflects data compiled over the life of the Site (EG&G 1992e) and shows the combinations of vehicle types involved in accidents and the number of accidents for each vehicle combination. The category "single vehicle" shows strictly the number of single vehicle accidents, thus it is only listed on one axis of the matrix.

Table 4.6-1. On-Site Vehicle Accident Matrix (1952-1991)

Vehicle Type	Private	Government	Commercial	Protective Force	Pedestrian/Cycle
Private	4	29	0	4	1
Government	–	3	2	0	1
Commercial	–	–	0	0	0
Protective Force	–	–	–	1	1
Pedestrian/Cycle	–	–	–	–	0
Single Vehicle	17	21	8	1	1

Axes in the above table indicate composition of both vehicles involved in accidents.

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Because of the small number of accidents that have occurred during the Site's operation and the Site's emphasis on safety, it is anticipated that these accidents will continue to be few in the future. For this reason, low-consequence, on-site traffic accidents are not considered further in this Cumulative Impacts Document. A high-consequence, low-probability traffic accident is considered in Section 5.6, "Impacts on Traffic and Transportation."

Transportation of Materials

The Site's Transportation Safety Manuals (Kaiser-Hill 1995d) incorporates federal, state, and DOE regulations and guidelines for packaging, marking, labeling, handling, and transport of radioactive and nonradioactive hazardous materials at the Site for both on-site and off-site shipments. The on-site transportation policy requires that all hazardous and radioactive materials be marked, labeled, handled, transported, and stored in approved shipping packages using methods and procedures designed to ensure compliance with applicable regulations unless an equivalent level of safety is provided for non-compliant on-site shipments. Government property is not permitted to be taken off-site without authorization, and then only with strict regulations governing materials handling and transport.

The Rocky Flats Transportation Safety Manual requires that transportation-related exposures and environmental impacts be as low as reasonably achievable in accordance with DOE Order O 460.1a, "Packaging and Transportation Safety" (DOE 1996) Outbound and inbound shipments by commercial carriers or by government-owned vehicles operated by other than government employees must be packaged, marked, labeled, and ready for transport in accordance with Department of Transportation regulations 49 CFR 100-199 and 350-399, Public Law 101-614 (training requirement), the Transportation Safety Act of 1990 and State of Colorado regulations on hazardous materials (which in general are based on the federal standards in 49 CFR and 40 CFR). DOE shipments must meet Department of Transportation regulations for transport of all materials, including special nuclear materials unless excluded under the Nuclear Weapons Safety Program (which are transported by DOE Transportation Safeguards System in accordance with DOE directive). Additional discussions of Federal, State, and Site requirements for shipping radioactive and hazardous materials on-site and off-site are provided in the Site Scott Anderson Report.

During past Site operations, raw materials, parts, nuclear weapons components, and waste generated during manufacturing constituted most of the material transferred on-site. Since production operations ceased, movement of raw materials, parts, and components has been reduced but not eliminated. Most on-site transfers involve movement of parts or materials from one storage location to another or movement of waste. Depending on the characteristics, quantity, and size of the items, the transport vehicle may be a pickup truck, enclosed van, or tractor trailer. Enclosed vehicles are always used to transfer radioactive or hazardous materials on-site, except low level waste or low level mixed waste. Personal vehicles are not used to transport radioactive or hazardous materials. The Site Scott Anderson Report (Kaiser-Hill 1996d) provides additional characterization of on-site traffic movements, types of vehicles, packaging configurations, and quantities of radioactive or hazardous materials.

Although some off-site transportation of material involves shipment by air, most material is shipped by land vehicles (primarily tractor trailers). Unclassified materials shipped by air typically include very small quantities of radioactive material for research and laboratory analysis usage. These shipments are made by freight rather than passenger carriers. Packages containing somewhat larger quantities (up to 15 grams) are sent to the International Atomic Energy Agency in Vienna. These shipments are made via freight carrier to New York then by passenger carrier to Vienna. All air shipments are packaged according to Department of Transportation and Nuclear Regulatory Commission requirements.

Off-site shipments of classified materials are handled by a DOE-contracted surface or air carrier, or DOE Transportation Safeguards System. Off-site shipments of other classified materials involving less-than-strategic quantities of special nuclear materials, and all truck shipments involving strategic quantities of special nuclear materials, are transported in Safe, Secure Trailers. These trailers are specially constructed and operated to provide maximum security and protection for the cargo.

The Shipment Mobility/Accountability Collection system is used at the Site to record inbound and outbound shipments of material. Table 4.6-2 provides a summary of unclassified material shipments from 1990 through 1994 (DOE 1995t). A further characterization of the types of radioactive and hazardous material shipments is provided in the Site Scott Anderson Report (Kaiser-Hill 1996d).

Table 4.6-2. Summary of Unclassified Material Shipments by Transportation Mode

	Air: Number of Shipments			Rail: Number of Shipments			Truck:[1] Number of Shipments			
Fiscal Year	Non-Haz[2]	Rad	Other-Haz	Non-Haz	Rad	Other-Haz	Non-Haz	Rad	Other-Haz	Total
1990	8,481	60	55	4[3]	0	0	6,356	311	609	**15,876**
1991	8,852	16	37	2	0	0	6,159	40	471	**15,577**
1992	7,647	21	49	1[4]	0	0	6,559	34	436	**14,747**
1993	5,918	29	41	0	0	0	7,479	25	497	**13,989**
1994	6,191	24	63	0	0	0	6,686	58	478	**13,500**

[1]Incorporates private motor, freight forward, U.S. mail, for-hire motor, and parcel service.
[2]Non-Haz = nonhazardous materials; Rad = radioactive materials; Other-Haz = other hazardous materials.
[3]Includes three reported shipments of materials to the Site originating by water.
[4]Includes one reported shipment of materials to the Site originating by water.

Transportation of hazardous and radioactive waste off-site is an important activity due to limited on-site storage capacity. Transuranic (TRU) waste is not currently shipped off-site because the WIPP repository in New Mexico is not yet accepting such waste. As of 1994, low-level, TSCA and hazardous waste were shipped from the Site. Shipments of low-level mixed waste to Envirocare of Utah began in 1995. Table 4.6-3 shows waste transportation activities under baseline conditions.

Table 4.6-3. Annual Off-Site Waste Shipments Under Baseline Conditions

Material	Destination	Number of Trips[1]	Volume (cubic yards)[1]
Residues (as TRU)	Waste Isolation Pilot Plant	0	0
TRU	Waste Isolation Pilot Plant	0	0
TRU-Mixed	Waste Isolation Pilot Plant	0	0
Low-Level	Nevada Test Site	57	927
	Hanford	0	0
Low-Level Mixed	Nevada Test Site	0	0
	Envirocare	36	754
RCRA	Waste Broker	7	48
TSCA	Waste Broker	1	2
TSCA (radioactive)	Hanford	1	4

[1]Based on 1994-1995 data.

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Water

The Site receives water regulated by the Denver Board of Water Commissioners from the Gross Reservoir via the South Boulder Diversion Canal (located along Highway 93 west of the Site) or the Ralston Reservoir via the Ralston Reservoir Pipeline. The South Boulder Diversion Canal is the primary source used for approximately eight months of the year. The Ralston Reservoir Pipeline is used during the winter months when water from the Canal is not available. Water from these sources is directed into a 1.5-million-gallon on-site holding pond. These water sources satisfy domestic, cooling tower, and irrigation needs at a rate of approximately 130 million gallons per year (Hartung 1995). This usage is expected to be reduced somewhat over time because the on-site worker population and site operations have been and will continue to be reduced until Site closure is accomplished.

Holding pond water is first pumped through a microscreen filter to remove algae before transfer to the domestic treatment system. In the winter months, this step is bypassed because algae populations are reduced. At the water treatment facility on the east side of the Site, the water undergoes treatment that removes particulates, adjusts the pH, and disinfects with chlorine.

These processes result in a purified domestic water stream and sludge that contains the particulates separated from the raw water and any chemicals used in the treatment process. The sludge is dried and then disposed of at the on-site sanitary landfill. The water treatment plant can process 1 million gallons of water per day. All distribution pumps are electric-powered. The distribution pumps are cycled automatically to maintain a minimum of 220,000 gallons in an elevated storage tank. An emergency generator is also available as a backup for water distribution.

The domestic distribution system serves both fire and domestic water requirements of the Site. All major buildings are served by closed-loop systems in which water can be supplied from either of two directions. This provides reliable service in the event of a line break. The distribution system has been sized to ensure adequate capacity for fire response requirements. One 500,000-gallon water storage tank for fire response and two fire pumps are located in Building 928. These fire pumps each have a capacity of 2,500 gallons per minute. One pump is diesel-driven, and one is electric. A second 500,000-gallon tank, typically used to store raw water for the Site, is also available for emergency use.

Cooling tower water is supplied directly from the on-site holding pond. There are eleven major cooling towers. Each cooling water system circulates cooling water to various processes or machinery in one or more building.

Steam

Steam is used at the Site as an energy source for building and process heating functions. All steam used on-site is generated by the central steam plant in Building 443 and is distributed at a pressure of 140 pounds per square inch (psi) to pressure-reducing stations located in or near major buildings. Steam pressure is reduced to 125 psi or lower and then distributed within the buildings.

The central steam plant has four 75,000-pound-per-hour boilers operating at 300 psi. The boilers each have a four-hour rating of 90,000 pounds per hour and are powered with natural gas. Fuel Oil No. 6 is used as a backup fuel supply during periods of peak natural gas demand or interruption of the natural gas supply. The plant produces approximately 425 million pounds of steam per year.

Water used for conversion to steam is recycled through the system. However, a certain amount of make-up water is required to keep the system fully charged. Product water from the waste system evaporator in Building 374 is the preferred source of make-up water. Raw holding pond water is used as a backup source of make-up water. Make-up water must be treated first in a demineralization process which uses cation/anion exchange. Sulfuric acid is used to regenerate the anion exchange resin, and sodium hydroxide is used to control the pH.

By-products from the steam generation process include exhaust gases from the boiler combustion process, boiler blowdown (a water stream produced during boiler cleaning operations), and waste solutions from the demineralizer and softener. Boiler blowdown is transferred to the sanitary waste water treatment plant. Waste solutions are processed in the Building 374 aqueous waste treatment system.

Natural Gas and Other Fuels

Natural gas is used at the Site for process and building heating. Natural gas is purchased from Public Service Company of Colorado under a series of contracts negotiated through the Defense Fuel Supply Center. Gas is purchased on an interruptible basis, which means that during regional peak demand periods, such as a period of sub-zero weather, the boilers, larger furnaces, and natural-gas-powered engines are switched to an alternate fuel source (fuel oil or propane). This arrangement ensures that gas the Site would otherwise consume is available for non-interruptible purposes such as home and hospital use. Natural gas is fed from an 8-inch natural gas line near the Site that supplies suburban Denver. The existing gas-reducing station at the Site reduces incoming gas pressure (250 to 300 psi) to the distribution pressure of 50 psi. The Site uses approximately 640 million cubic feet of natural gas per year.

Approximately 85% of the natural gas used is associated with the steam plant boilers in Building 443. Other major users of natural gas include the waste system evaporator in Building 374 and heating systems in all of the major buildings. Other equipment powered by natural gas includes water heaters, electrical generators, boilers, space heaters, and internal combustion engines. Combustion emissions are quantified in Section 4.5, "Air."

Historically, fuel oil No. 6 was used as a backup for natural gas in the central steam plant. Fuel oil was stored in an 800,000-gallon tank and a 1,900,000-gallon tank, providing adequate fuel for 150 days of operation without natural gas. No actual use of fuel oil has been required as a backup fuel supply for several years. Because the use of fuel oil is minimal, the supply is being downsized to 700,000 gallons, which will provide a 30-day supply under winter conditions. The excess fuel oil supply on site was sold, and two large tanks that were used to store the oil have been decommissioned, dismantled, and removed from the site.

Diesel fuel is used to power the Site's emergency electrical generators, as a backup fuel for hot-water heating boilers, and for diesel-powered vehicles and construction equipment. Periodic use of the diesel-powered emergency generators and firing of the heating boilers account for most of the consumption during normal Site operations. Total storage capacity for diesel fuel is 115,430 gallons.

Gasoline is used as fuel for one of the emergency electrical generators, Site vehicles, and miscellaneous equipment. A 14,000-gallon underground storage tank and pumps are located at the Site garage. Propane is also used as a backup for some natural-gas-powered processes and activities and for heating purposes at the 750 and 904 Pads.

Electricity

The Site purchases electrical power from Public Service Company of Colorado at 115 kilovolts and uses 12.5 to 13 gigawatt-hours per month. Four main substations, with a total capacity of 37,400 kilovolts peak, are served. Incoming voltage is transformed to 13.8 kilovolts and distributed to various building substations, where it is stepped down again to 2,400 or 480 volts. These substations have been designed so that one-half of the transformer capacity would be sufficient to sustain all normally connected load.

Emergency electrical power is provided by approximately 30 on-site diesel generators. In the event of total power loss from off-site sources, these generators can power critical functions such as ventilation, humidity control, public address capabilities, alarm systems, and building lighting. All emergency power generators operate on diesel fuel, which is supplied by an outside vendor. The fuel is transported via truck and transferred to underground storage tanks. For most generators, fuel is transferred from the underground storage tank to a day tank for immediate use.

Most other major buildings also have battery-powered uninterruptible power supplies for critical systems. Building 127 contains 84 lead acid batteries to ensure an uninterruptible power supply for the Central Alarm Station and security operations.

Nitrogen Gas

Nitrogen gas is used extensively on-site, primarily to provide inert atmospheres for gloveboxes and plutonium storage vaults. Nitrogen is provided by an on-site air separation plant located in Building 223. This plant is capable of producing 183,000 standard cubic feet per hour and consistently produces 125,000 standard cubic feet per hour. The nitrogen plant receives atmospheric air as the input stream and generates product in both liquid and gas forms. A separate by-product stream of hydrocarbons and oxygen-enriched air is produced and vented to the atmosphere. A second stream consisting of carbon dioxide, water vapor, and oxygen-enriched air is also produced and vented to the atmosphere. Nitrogen gas is supplied to buildings via a gas supply line. Backup supplies are stored in liquid form in tanks at the nitrogen plant.

4.8 Human Health and Safety

The two primary concerns of the Department of Energy are the health and safety of its workers and the general public and protection of the environment. Extensive monitoring and mitigation programs are in place to ensure that these concerns are addressed at the Site. This section provides an overview of the Site's health and safety programs and presents an estimate of the baseline risks resulting from routine operations and past contamination events at the Site. Appendix B ("Human Health and Safety") provides additional details on radiological and nonradiological human health and safety. Table 4.8-1 presents a summary of estimated human health impacts under CID *baseline* case conditions.

Table 4.8-1. Summary of Baseline Case Human Health Risks at the Site

Receptor	Exposure Pathways Considered	Estimated Annual Health Effects	Comments and Assumptions
Radiological–Worker			
Site Radiation Worker (Collective Dose)	Internal radiation exposure (all pathways)	1.7 person-rem (0.0007 excess fatal cancer)	Derived from actual monitoring data. Based on 29 internal exposures. The DOE limit for total annual individual exposure is 2 rem per year.
	External radiation exposure (all pathways)	263 person-rem (0.1 excess fatal cancer)	Derived from actual monitoring data. The DOE limit for total annual individual exposure is 2 rem per year.
Co-Located Site Worker (Individual Dose)	Air inhalation	0.29 millirem (1 in 10 million increased probability of fatal cancer)	Air modeling calculation. Receptor assumed to be located at point of maximum contaminant concentration.
Radiological—Public			
Collective General Public Within 50 Miles of Site	Air inhalation	0.27 person-rem (0.0001 excess fatal cancer)	Equivalent to much less than 1 fatal cancer among population analyzed.
Maximally Exposed Individual	Air inhalation, soil ingestion, ground water ingestion, and ground-plane irradiation	0.14 millirem (7 in 100 million increased probability of fatal cancer)	Assumed to be at Site boundary . Recommended exposure limit by the International Commission on Radiation Protection is 100 millirem per year.
Nonradiological—Worker			
Co-Located Site Worker	Air inhalation - non-cancer health risk	Hazard index = 1.1 from all chemicals	Potential cause for concern since hazard index slightly exceeds 1.0.
	Air inhalation - cancer health risk	6 x 10^{-5} (6 in 100,000) excess lifetime cancer risk	Estimate is within EPA's *National Contingency Plan* range of 10^{-6} to 10^{-4} (or 1 in 1 million to 1 in 10,000).
Site Worker (General)	Worker injury and illness	253 total recordable injury and illness cases	DOE Site Incidence Rate = 4.3 per 200,000 hours worked (comparable private industry rate = 8.5).
Nonradiological—Public			
Maximally Exposed Individual	Air inhalation - non-cancer health risk	Hazard index = 1.2 from all chemicals	Potential cause for concern since hazard index slightly exceeds 1.0.
	Air inhalation - cancer health risk	2 x 10^{-7} (2 in 10 million) excess lifetime cancer risk	Estimate well below EPA's *National Contingency Plan* "acceptable" range (i.e., below 10^{-6}).

Since workers and the public may be exposed to radiation or chemicals of concern on differing levels, this section has been arranged to address the four major categories of concern in the following order: 1) radiological health and safety for the worker, 2) radiological health and safety for the public, 3) nonradiological health and safety for the worker, and 4) nonradiological health and safety for the public.

4.8.1 Radiological Health and Safety–Worker

The guiding principle for radiological protection of the Site worker is to keep radiation levels "As Low As Reasonably Achievable," also known as ALARA. The ALARA policy is designed to keep radiation exposure to both workers and the public well below established limits and to prevent unnecessary exposure.

Under normal working conditions at the Site, workers may be exposed to radiation in a controlled environment. Worker exposure is generally divided into two broad categories: internal and external.

- *Internal exposures* occur when radioactive particles are ingested, inhaled, or injected into a wound. As a result of stringent protective measures and training, internal exposures at the Site are infrequent and typically occur only under abnormal or accident conditions.
- *External exposures* occur as a result of direct radiation emitted from radioactive materials. Workers who perform their jobs in the presence of gamma, neutron, or beta radiation sources receive external doses. External dose may be reduced by protective measures and procedures, but a certain amount of exposure will continue to occur at the Site as long as nuclear materials continue to be stored there.

The following section describes the programs and procedures that are in place to limit worker dose.

Site Radiological Protection Program

A combination of administrative controls, engineered controls, and personal protective equipment is used at the Site to limit radiation exposure to the worker.

- Administrative controls include procedures to limit access to and minimize duration of activities in high radiation areas.
- Engineered controls include use of gloveboxes (sealed and filtered environments) for working with radioactive materials.
- Personal protective equipment includes use of respirators to prevent inhalation of airborne radioactive particles and air sampling monitors and alarms to alert workers to the presence of such particles.

The Site's personnel monitoring program sets standards and procedures for the measuring and reporting of both internal and external doses to individual workers, as described below.

Bioassay techniques are used to monitor internal exposures. These techniques include urinalysis, fecal sample analysis, and nasal/mouth sample analysis. Special equipment is available to detect radioactive material in the lungs or in open wounds. Bioassay is conducted on a routine basis for all radiation workers. Additional bioassay is conducted following any incident where worker contamination occurs or intake is suspected.

Dosimeters are used to monitor external radiation. All personnel entering radiological control areas are required to wear thermoluminescent dosimeters, which measure dose from gamma/X-rays, neutrons, and beta radiation. These dosimeters are returned to the dosimetry laboratory on at least a quarterly schedule for analysis of worker doses. Results are recorded and reported to employees and their supervisors. Special dosimeters, such as thermoluminescent dosimeter wrist badges, are used for specific jobs as the need is identified by a health physicist or radiological engineer. Direct-reading dosimeters are used on special projects where real-time reporting of doses is necessary. With this type of dosimeter, workers are able to self-monitor their doses and leave the area as they approach the pre-determined limit.

DOE Regulations and Guidelines

Regulations limit the amount of radiation individual workers at the Site may receive in a year and on a lifetime basis. Exposure to radiation is measured in units called "rem," which express dose on a common scale from all types of ionizing radiation based on the potential of that dose to cause biological damage. Units of 1/1000 of a rem, or 1 millirem, are often used to more conveniently express the low doses typical for workers at the Site.

DOE worker dose restrictions are outlined in federal regulation 10 CFR 835. The annual limit for whole body exposure is 5 rem; however, DOE has set a lower annual limit of 2 rem, which is called the administrative control limit. As part of its site-specific ALARA program, the Site has set an even lower annual limit of 750 millirem, which is applicable to most situations and workers at the Site. These regulations and guidelines are summarized in Table 4.8-2. In 1996, six workers received external doses exceeding the 750 millirem limit, three were planned (with prior management approval) and three were unexpected. All six doses were below the DOE administrative control limit of 2 rem, however.

Table 4.8-2. DOE Radiation Worker Dose Restrictions

Regulating Authority	Annual Dose Limit or Guideline
Federal Regulation 10 CFR 835	5 rem
DOE	2 rem
Rocky Flats Environmental Technology Site	750 millirem (0.75 rem)

Because all worker doses have been below the threshold for acute radiation injury, individual worker exposure is not within the context of this CID. Collective dose, which is the dose of a group of people, is a more meaningful measure of the relative impact of dose. Therefore, further quantitative discussion of worker dose will refer to collective dose, which is expressed in units of person-rem (i.e., average individual dose in rem multiplied by the size of the population being analyzed).

Calculating Radiological Dose and Health Effects

Information on the presence of radioactive material in the environment is typically collected in terms of concentration. To translate these concentrations into annual dose, certain assumptions are made regarding the amount of each radionuclide that the body would be exposed to or that would be taken into the body during a one-year period. The physical and chemical behavior within the body and the type and quantity of radiation specific to each radionuclide are also taken into consideration.

Based on this type of information, dose conversion factors have been developed and adopted by DOE for each radionuclide, for specific pathways, and for specific parts of the body (DOE 1988a and 1988b). The dose conversion factor for each radionuclide is multiplied by the radionuclide concentration for a specific pathway to determine its "dose equivalent." Dose equivalents allow for comparisons of dose resulting from exposures to differing types of radiation to different body organs. Dose equivalents can in turn be used to calculate internal dose, external dose, or total dose, as summarized below:

- **Internal dose.** Internal dose results from intake to the body of radioactive material and is expressed as "committed effective dose equivalent." It accounts for the total dose effect on the individual over a 50-year period as a result of one year's intake of material. This approach is necessary because internal dose is not limited to a specific time in the presence of a radioactive source; rather, when radioactive materials are taken into the body, they continue to give dose to the body as long as they are present.

- **External dose.** External dose is received only during the time of direct exposure and is expressed as "effective dose equivalent."
- **Total dose.** Internal and external dose can be summed to calculate dose to the person as a whole. This calculated dose is called "total effective dose equivalent."

The basic unit of measure for all of these dose expressions is rem, which (as noted above) expresses dose on a common scale from all types of ionizing radiation based on the potential of that dose to cause biological damage.

Once dose has been determined, it is possible to estimate health effects. These effects can differ, however, with differing populations. Sensitive populations (such as infants or children) are more prone to health effects from radiation exposure, for example, than healthy adults. To account for these differences, the International Commission on Radiological Protection has developed recommended "health effects conversion factors" based on actual human exposure studies (ICRP 1991a). These conversion factors are expressed in units of "increased probability of fatal cancer per rem of radiation dose" for an individual and "excess number of cancer fatalities per person-rem of exposure" among a population.

The conversion factor for workers is 4×10^{-4}. The conversion factor for the general public is 5×10^{-4}. In effect, risks to the general public are estimated more conservatively than risks to workers to account for more sensitive portions of the population. When the appropriate conversion factor is multiplied by the dose to an individual or population, it is possible to determine, respectively, 1) the increased lifetime probability of fatal cancer to an individual and 2) the excess number of cancer fatalities among a population.

The International Commission on Radiological Protection has also developed health effects conversion factors to calculate other types of health effects (i.e., not just cancer fatalities); however, this CID focuses its analysis on fatal cancers as representative of human health impacts.

Radiation Worker Internal Dose

Internal exposures at the Site are largely avoidable through use of engineered controls as discussed above. However, a limited number of internal exposures continue to occur, mostly as a result of unexpected conditions or occurrences. Internal doses to radiation workers at the Site are based on actual data from monitoring and bioassay results.

In 1996, there were 34 recorded internal exposures at the Site. Based on these internal exposures, the collective internal dose at the Site was 1.7 person-rem per year of committed effective dose equivalent. Applying the health effects conversion factor for workers (4×10^{-4}), the excess number of latent cancer fatalities among Site radiation workers from this dose is estimated at 0.0007, or much less than 1 excess fatal cancer.

Internal dose accounted for approximately 0.6% of the total annual dose on-site. Since internal dose is very low relative to external dose, no further discussion of internal dose for the Site radiation worker is included.

Radiation Worker External Dose

External dose estimates for radiation workers are derived from data from individual dosimeter readings. The external dose baseline was developed using 1996 dose data and is estimated at 263

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person-rem. Applying the health effects conversion factor for workers (4×10^{-4}), the excess number of latent cancer fatalities among Site radiation workers from this dose is estimated at 0.11, or much less than 1 excess fatal cancer. Work groups receiving the highest dose included radiological control technicians, maintenance personnel, and nondestructive testing and assay personnel.

Co-Located Worker Dose

Co-located workers are Site workers who do not necessarily perform work that results in radiological exposure, but by their presence at the Site may be exposed to releases that occur. Air is the only pathway that substantially affects the co-located worker. Inhalation of resuspended soil particles is considered as part of the analysis for the air pathway.

Whereas dose to Site radiation workers was determined based on actual bioassay and dosimetry results, dose to the co-located worker was modeled, or calculated, based on air monitoring data as presented in Section 4.5.2, "Radiological Air Quality." A very conservative approach to assessing the co-located worker dose was used. This individual was assumed to be identical to the maximally exposed individual, a hypothetical member of the public who is potentially exposed to the greatest dose from Site emissions. CAP-88PC was used to estimate the dose to the co-located worker 100 meters downwind of the emission point and every 100 meters out to the site boundary. A Geographic Information System (GIS) was used to overlay doses maps from each emission point and determine the on-site location of the highest dose. For modeling purposes, two key assumptions were made: 1) that the co-located worker was not wearing a respirator, and 2) that the co-located worker was continually located at the point of maximum contaminant concentration (i.e., for a Site worker not wearing a respirator). The latter assumption is hypothetical and conservative, since no actual worker is likely to be continually present at such a point.

Dose to the co-located worker was calculated on an individual rather than a collective basis. The maximum internal dose to a co-located worker under baseline conditions is estimated at 0.29 millirem per year of committed effective dose equivalent. Applying the health effects conversion factor for workers (4×10^{-4}), the increased lifetime probability of fatal cancer from this dose is estimated at 1×10^{-7}, or 1 in 10 million. For more information on air modeling calculations used to derive co-located worker dose, refer to Appendix B ("Human Health and Safety").

4.8.2 Radiological Health and Safety–Public

The presence of radioactive materials is routinely monitored at the Site and in the surrounding area to allow for evaluation of potential health effects to the general public. For purposes of this analysis, "general public" is defined as the collective general public within 50 miles of the Site. Radiological health effects to the maximally exposed individual are also considered in this section. The maximally exposed individual is a hypothetical member of the general public who resides near the Site at a hypothetical location where maximum dose from all pathways is received.

Radiation Protection Standards

Radiation protection standards for the public are based on recommendations of national and international radiation protection advisory groups and on standards set by other federal agencies. The standard recommended by the International Commission on Radiological Protection and adopted by DOE for total dose resulting from all pathways is 100 millirem per year to the maximally exposed individual. The standard as defined under the Clean Air Act's National Emission Standards for Hazardous Air Pollutants for the air pathway only is 10 millirem per year to an individual. Appendix B ("Human Health and Safety") describes concepts and definitions relating to radiological dose and health effects in more detail.

Background Radiation

Environmental radiation always exists and at varying levels. Sources of environmental radiation include cosmic rays, radioactive material naturally present in soil and rock, radioactive material naturally occurring in the human body, and naturally occurring airborne radionuclides such as radon gas. The dose received by people living in a specific geographical location depends on the extent to which these natural sources exist and varies with the geology and altitude of the location.

The annual natural background radiation dose for Denver-area residents is approximately 418 millirem per year (NCRP 1987a and 1987b). This background dose does not include other voluntary doses that might be received such as medical X-rays.

Doses described below are in addition to the background dose received by each Denver-area resident. In some cases, however, it is not feasible to separate background sources from sources at the Site; in these cases, a conservative approach is taken and the full dose contribution is attributed to the Site.

Dose to the General Public

Dose to the general public was modeled based on air monitoring data as presented in Section 4.5.2, "Radiological Air Quality." Air is the only pathway that substantially affects the average member of the general public. Inhalation of resuspended soil particles is considered as part of the analysis for the air pathway.

Internal dose to the general public is evaluated collectively and expressed in units of person-rem. As required by DOE Order 5400.5, "Radiation Protection of the Public and Environment," collective dose is calculated for the population residing within a 50-mile radius from the center of the Site.

The collective internal dose to the general public under baseline conditions was developed using 1993 air monitoring data (see Section 4.5.2, "Radiological Air Quality" for references and additional detail) and is estimated at 0.27 person-rem per year. This dose is in addition to the background dose received by each Denver-area resident. Applying the health effects conversion factor for the general public (5×10^{-4}), the excess number of latent cancer fatalities among the general public from this dose is estimated at 1×10^{-4} (i.e., 0.0001), or much less than one excess fatal cancer for the population analyzed. This dose estimate is more plausible and representative of actual conditions surrounding the Site than the estimate for the maximally exposed individual, which is a hypothetical worst-case scenario.

Dose to the Maximally Exposed Individual

As noted above, the maximally exposed individual is a hypothetical member of the general public who resides near the Site at a hypothetical location where maximum dose from all pathways is received. This individual is assumed to reside at this location 24 hours per day, 365 days per year, for one year. The committed dose as a result of this intake is calculated for a period of 50 years. In reality, maximum concentrations of radiological contaminants do not occur for all media at the same geographic location, and an individual would not remain at the location on a continuous basis. Therefore, the maximally exposed individual demonstrates the worst case and is not truly representative of any actual member of the public. The selection of radionuclide concentrations to model each exposure pathway requires several considerations. The selection of "realistic but conservative" concentration values are necessary to provide a reasonable estimate of the worst-case exposure, without introducing excessive conservatism. This CID provides a dual track approach, providing a bounding exposure scenario ("bounding scenario") that includes use of maximum observed concentrations for each exposure media, and a more realistic scenario based on reasonable radionuclide concentrations for a nearby residence ("realistic scenario"). This scenario is consistent with other environmental exposure analyses performed by the Site. The realistic scenario is based on the analysis performed in the *1994 Site Environmental Report.*

Assumptions on drinking water radionuclide concentration make a significant difference on the estimated dose to the maximally exposed individual. For the bounding scenario, the calculated risk from ground water ingestion presents the largest potential dose and associated risk to the maximally exposed individual when compared to other pathways. This is inconsistent with other maximum exposure individual analyses performed previously. However, it is important to note that conservative assumptions were used in making the ground water dose calculation. For the bounding scenario, the maximally exposed individual is assumed to consume his or her entire water intake from the upper aquifer at the Site boundary, which does not actually provide adequate flow for a viable ground water well. Calculations for these two scenarios are presented below.

Pathways potentially affecting the maximally exposed individual are air inhalation, surface water ingestion, ground water ingestion, soil ingestion, and ground-plane irradiation. Each of these pathways is briefly discussed below. Site-specific studies have shown that exposures through consumption of foodstuffs are relatively insignificant contributors to public radiation dose (Fraley 1992); therefore, this pathway is not further considered. Swimming is also dismissed as a pathway because no surface water leaving the Site is discharged to a body of water where swimming is practiced.

AIR PATHWAY. Radioactive air emissions occur from both building and area (i.e., contaminated soil) sources at the Site. For the bounding scenario, actual emissions are monitored at numerous locations and have been modeled according to EPA methodology (40 CFR 61Hb). Air pathway calculations for the bounding scenario were modeled based on air monitoring data as presented in Section 4.5.2, "Radiological Air Quality." Inhalation of resuspended soil is considered as part of this analysis. For the realistic scenario, the maximally exposed individual was assumed to breathe a measured off-site air concentration selected as the closest plant perimeter air sampling location upwind of residential housing located near the Site in a Southeast direction.

GROUND WATER PATHWAY. Ground water is sampled and monitored at numerous locations on-site and some locations off-site as discussed in Section 4.4.2, "Ground Water Quality." Based on data from alluvial wells at the eastern Site border, it is possible that a member of the public residing near the eastern boundary of the Site and using a shallow drinking-water well could be exposed to radioactive contaminants. It is not believed that such wells actually exist or that such water is being consumed. However, to calculate the most conservative risk to the maximally exposed individual, this pathway has been included.

For the bounding scenario, the maximally exposed individual is assumed to consume all drinking water from a shallow ground water well near the Site. The well selected monitors water from the uppermost aquifer at the Site. Many weathered-bedrock wells within this aquifer have slow water-level recovery times indicative of low ground water yield, typically less than one gallon per minute. For this reason, use of the uppermost aquifer as a ground water source is improbable. The highest reported levels for each radionuclide were selected for use in this bounding scenario. It is postulated that contaminated stream sediments might be associated with the radionuclide concentration levels in this well. Additional characterization and sampling are ongoing to further evaluate the reasons for the occurrence of elevated radionuclide concentrations. These radionuclide concentrations and resulting doses are indicated in Table 4.8-3. For the realistic scenario, the maximally exposed individual is assumed to consume drinking water at the volume-weighted radionuclide activities of surface waters released from the Site.

SURFACE WATER PATHWAY. Surface water leaves the Site from monitored discharge points in accordance with the Site's NPDES permit as described in Section 4.4.4, "Surface Water Quality."

Surface water effluents discharged from the Site are diverted around Great Western Reservoir and Standley Lake, eventually discharging to the South Platte River. Thus, no Site surface water goes directly to any local drinking water supply. Thus, surface water ingestion dose is not considered for the bounding scenario, because it is lower than the ground water ingestion dose. Since it would not be possible for the maximally exposed individual to receive dose simultaneously from both these pathways, only the larger dose (from ground water) is included in the total.

SOIL PATHWAY. Low levels of soil contamination exist in areas surrounding the Site as described in Section 4.3, "Soils." Consideration of the effects of soil ingestion is consistent with EPA's recommended risk assessment approach as outlined in *Risk Assessment Guidance for Superfund* (EPA 1989a). Therefore, the effect of soil ingestion on the maximally exposed individual is considered as part of both scenarios. Intake from soil ingestion is calculated for the bounding scenario based on the maximum off-site soil concentration as determined from the *Comprehensive Appraisal of Plutonium-239 and -240 in Soils of Colorado* (Litaor 1995). For the realistic scenario, a concentration was selected from a soil sampling site representative of soil for residences nearest the Site.

GROUND-PLANE IRRADIATION PATHWAY. Ground-plane irradiation by external penetrating radiation is a potential pathway, but it is a small contributor to public dose. The source of ground-plane irradiation to the public is external penetrating radiation emitted from radioactive contamination in off-site surface soils. Site radioactive materials that are soil contaminants contribute relatively little external penetrating radiation; therefore, risk of exposure to the public from this pathway is less than other pathways. For the bounding scenario, ground-plane irradiation is calculated based on maximum off-site soil concentrations (Litaor 1995), and for the realistic scenario, based on the radionuclide concentration representative of the soil for residences nearest the Site.

TOTAL DOSE TO THE MAXIMALLY EXPOSED INDIVIDUAL. Since the maximally exposed individual represents a hypothetical individual, dose to the maximally exposed individual is calculated on an individual rather than a collective basis. Both internal doses (e.g., from air inhalation) and external doses (e.g., from ground-plane irradiation) are considered for the maximally exposed individual. These doses are summed to provide the total effective dose equivalent (see Section 4.8.1, "Radiological Health and Safety–Worker," for more information).

Despite the extremely conservative assumptions used in the bounding scenario to calculate dose to the maximally exposed individual, the total effective dose equivalent under baseline conditions is estimated at 17 millirem per year, only 17% of the allowable 100 millirem annual dose to the public. For the realistic scenario, the maximally exposed individual is estimated to receive 0.14 millirem per year, an extremely small fraction of the public dose limit. These estimated doses are in addition to the annual background dose received by each Denver-area resident. Applying the health effects conversion factor for the general public (5×10^{-4}), the increased lifetime probability of fatal cancer for the bounding and realistic scenarios are estimated at 9×10^{-6} or 7×10^{-8} respectively.

Table 4.8-3 summarizes concentrations and doses by media for the maximally exposed individual for the bounding scenario. Table 4.8-4 summarizes concentrations and doses by media for the realistic scenario. Dose is provided for each of the pathways described above, then totaled for all pathways.

Table 4.8-3. Bounding Scenario - Total Dose to the Maximally Exposed Individual under Baseline Conditions

Radionuclide	Concentration	Dose Conversion Factor[1]	Annual Dose Equivalent (millirem)[2]	Increased Probability of Fatal Cancer[3]
Air Inhalation[4]				
–	–	–	**0.0052**	**3×10^{-9}**
Ground Water Ingestion				
Plutonium-239/-240	2.20×10^{-9} μCi/ml	$3.14 \times 10^{+9}$	6.91	3.45×10^{-6}
Americium-241	4.70×10^{-10} μCi/ml	$3.65 \times 10^{+9}$	1.72	8.58×10^{-7}
Uranium-233/-234	2.20×10^{-8} μCi/ml	$1.97 \times 10^{+8}$	4.34	2.17×10^{-6}
Uranium-238	1.50×10^{-8} μCi/ml	$1.68 \times 10^{+8}$	2.52	1.26×10^{-6}
–	–	–	**15.5**	**8×10^{-6}**
Surface Water Ingestion[5]				
Plutonium-239/-240	1.21×10^{-10} μCi/ml	$3.14 \times 10^{+9}$	0.38	1.90×10^{-7}
Americium-241	2.40×10^{-11} μCi/ml	$3.65 \times 10^{+9}$	0.08	4.38×10^{-8}
Uranium-233/-234	1.19×10^{-9} μCi/ml	$1.97 \times 10^{+8}$	0.235	1.17×10^{-7}
Uranium-238	1.82×10^{-9} μCi/ml	$1.68 \times 10^{+8}$	0.306	1.53×10^{-7}
–	–	–	**1.01**	**5.04×10^{-7}**
Soil Ingestion				
Plutonium-239/-240	6.47 pCi/g	0.157	1.02	5.11×10^{-7}
Americium-241	1.29 pCi/g	0.183	0.236	1.18×10^{-7}
–	–	–	**1.25**	**6×10^{-7}**
Ground-Plane Irradiation[6]				
Plutonium-239/-240	0.320 μCi/m^2	0.082	0.026	1.31×10^{-8}
Americium-241	0.0640 μCi/m^2	2.99	0.191	9.57×10^{-8}
–	–	–	**0.218**	**1×10^{-7}**
Total	–	–	**17**	**1×10^{-5}**

[1]Multiplying the concentration by the dose conversion factor yields the dose equivalent. Dose conversion factors include these intake rates: Water: 2.1 quarts/day. Air: 266 milliliters/second. Soil: 0.003 ounces/day. Units for dose conversion factors are as follows: water ingestion, millirem x ml/μCi; soil ingestion, millirem x g/pCi; ground-plane irradiation, millirem x m^2/μCi. (DOE 1988a & 1988b).

[2]For external dose, effective dose equivalent is given; for internal dose, committed effective dose equivalent is given.

[3]Multiplying the dose equivalent by the health effects conversion factor for the general public (5×10^{-4}) yields the increased lifetime probability of fatal cancer for the maximally exposed individual (ICRP 1991a).

[4]The dose for air was calculated directly using CAP88-PC computer code.

[5]Surface water ingestion is not included in the total maximally exposed individual dose because it is bounded by ground water dose and both could not occur simultaneously.

[6]Areal concentration was calculated from volume concentration assuming a soil density of 1 gram per cubic centimeter and a sampling depth of 5 cm, with all plutonium from the sample concentrated at the surface.

Table 4.8-4 Realistic Scenario - Total Dose to the Maximally Exposed Individual under Baseline Conditions

Radionuclide	Concentration[2]	Dose Conversion Factor[3]	Annual Dose Equivalent (mrem)[4]	Increased Probability of Fatal Cancer[5]
Air Inhalation[1]				0
			0.080	**4E-08**
Ground Water Ingestion				
Pu-239/240	2.0E-12	3.14E+09	0.01	3.14E-09
Am-241	3.0E-12	3.65E+09	0.01	5.48E-09
U-233/234	0	1.97E+08	-	0.00E+00
U-238	1.0E-11	1.68E+08	0.00	8.40E-10
			0.02	**9E-09**
Surface Water Ingestion[6]				
Pu-239/240		3.14E+09	-	0.00E+00
Am-241		3.65E+09	-	0.00E+00
U-233/234		1.97E+08	-	0.00E+00
U-238		1.68E+08	-	0.00E+00
			-	**0.00E+00**
Soil Ingestion				
Pu-239/240	1.8E-01	0.157	0.03	1.41E-08
Am-241	3.6E-02	0.183	0.007	3.29E-08
			0.03	**2E-08**
Ground-Plane Irradiation				
Pu-239/240	9.00E-03	0.082	0.001	3.69E-10
Am-241	1.8E-03	2.99	0.005	2.69E-09
			0.006	**3E-09**
Total			**0.140**	**7E-08**

1 Air Inhalation dose was determined from measured air concentration and dose conversion factors presented in Site Environmental Report for 1994.
2 All radionuclide concentrations were taken from Site Environmental Report for 1994. All dose conversion factors are consistent with those used in the bounding scenario.
3 Multiplying the concentration by the dose conversion factor yields the dose equivalent. Dose conversion factors include these intake rates: Water: 2.0 liters/day. Soil: 0.004 ounces/day. Units for dose conversion factors are as follows: water ingestion, millirem x ml/µCi; soil ingestion, millirem x g/pCi; ground-plane irradiation, millirem x m^2/µCi. (Site Environmental Report for 1994).
4 For external dose, effective dose equivalent is given; for internal dose, committed effective dose equivalent is given.
5 Multiplying the dose equivalent by the health effects conversion factor for the general public (5×10^{-4}) yields the increased lifetime probability of fatal cancer for the maximally exposed individual (ICRP 1991a).
6 Surface water ingestion is not included in the total maximally exposed individual. Volume-weighted radionuclide activities of released waters were used to determine water ingestion dose.

Dose to the maximally exposed individual is also reported in the Site's annual environmental report. The committed effective dose equivalents reported for the years 1990 through 1994 are shown in Table 4.8-5. Differences in estimates between the environmental reports and the bounding scenario can be attributed to the highly conservative assumptions used in calculating the maximally exposed individual dose. Specifically, ground water data from boundary wells located on the eastern side of the Site were used for the bounding scenario analysis but were not considered in the annual environmental reports. More conservative soil concentration data were also used. The realistic scenario uses the methodology of the bounding scenario, but more realistic radionuclide concentrations are reflected in the 1994 Site Environmental Report. This scenario provides a more accurate estimation of the maximum individual dose, and provides a more accurate breakdown of dose by exposure pathway.

Table 4.8-5. Comparison of Dose to the Maximally Exposed Individual as Calculated in this CID and Site Environmental Reports

Year	Committed Effective Dose Equivalent from All Pathways (millirem)	Source
1990	0.52	1990 Site Environmental Report
1991	0.32	1991 Site Environmental Report
1992	0.46	1992 Site Environmental Report
1993	0.48	1993 Site Environmental Report
1994	0.10	1994 Site Environmental Report
Bounding Scenario	17.0	------------------
Realistic Scenario	0.14	------------------

4.8.3 Nonradiological Health and Safety–Worker

Workers at the Site may be exposed to nonradiological hazards that are typical of general industry. These hazards include various energy sources and toxic chemicals that could cause occupational injuries or illnesses. Occupational safety and health programs have been established to minimize physical and chemical hazards to the worker. Engineering and administrative controls, worker training, and use of personal protective equipment all help to ensure that injuries are minimized and occupational exposure to contaminants is maintained within the ALARA objective.

Site Nonradiological Protection Program

The contractors at the Site must comply with DOE and OSHA requirements to provide and implement nonradiological health and safety programs to protect Site workers. DOE Order O 440.1, *Worker Protection Management for DOE Federal and Contractor* Employees (DOE 1995ee) invokes the OSHA health and safety standards for general industry (29 CFR 1910) and construction (29 CFR 1926) and provides additional programmatic requirements. The *Industrial Health and Safety Program* (EG&G 1992h) describes the program as defined by applicable DOE Orders and industry guidelines. Specific requirements are detailed in the *Rocky Flats Health and Safety Practices Manual* (Kaiser-Hill 1996b). Regarding chemical safety for hazardous waste, OSHA regulations in 29 CFR 1910.120 specifically require implementation of employee health and safety plans for hazardous waste operations and treatment, storage, and disposal facilities. Established OSHA programs at the Site include:

- Hazard communication program to provide Site employees with information and training on hazardous chemicals in their work area.
- Medical surveillance program to monitor Site employees when engaged in work requiring respirator use or when potentially exposed at or above permissible exposure limits as set by OSHA.
- Air monitoring program to assess potential chemical exposures and determine levels of protection.
- Engineering controls, work practices, and personal protective equipment requirements to minimize the potential for worker exposures.

- Decontamination procedures to prevent the spread of contamination due to hazardous waste work.
- Confined space entry program to set safety requirements for entry into permit-required confined spaces.
- Materials handling program to set requirements for handling containers of hazardous substances and contaminated soils, liquids, and other hazardous residues.
- Formalized written health and safety plans to define health and safety practices and procedures for hazardous waste workers.
- Emergency response program to address personnel roles, lines of authority, safe distances, medical treatment, and procedures during an emergency.
- Training program to train new employees on work-related hazards and update existing employees with new information.

These programs are further described in the RFETS *Health and Safety Practices Manual* (Kaiser-Hill 1996b) and *Environmental Restoration Health and Safety Program Plan* (EG&G 1994dd). They address such on-site health concerns as toxic chemicals, heavy metals, carcinogens, noise, lasers, heat and cold stress, and blood-borne pathogens. The programs are administered by the on-site departments of Industrial Hygiene and Occupational Safety. Sampling and monitoring programs at the Site are structured to assess and quantify potential contaminants on-site. These programs include:

- Toxic chemical control program.
- Lead control program.
- Pesticide control program.
- Carcinogen control program.
- Beryllium protection program.
- Hearing conservation program.
- Ergonomics program.
- Blood-borne pathogen control program.
- Asbestos abatement program.

Data obtained from sampling investigations are evaluated to determine engineering or administrative controls and personal protective equipment requirements. Assessments are also performed on a regular basis to determine if existing control measures are adequate to maintain health exposures below permissible contaminant exposure limits as set by OSHA.

Permissible Exposure Limits

In 1971, OSHA adopted permissible exposure limits for chemicals and air contaminants as prescribed in 29 CFR 1910.1000. This standard states that no employer shall expose an employee to occupational health hazards over the permissible exposure limits. These limits are set for specific air contaminants averaged over eight hours. Toxic and hazardous substances are listed in 29 CFR 1910.1001-1450. If there is no OSHA permissible exposure limit for a certain air contaminant, then OSHA may employ exposure values provided by other agencies, including the American Conference of Governmental Industrial Hygienists and the National Institute for Occupational Safety and Health. The Site uses a combination of engineering controls, safety practices, training programs, air monitoring, health and safety plans, and personal protective equipment to reduce air contaminant exposures to levels below permissible exposure limits.

Exposure Pathways

The primary route of exposure for nonradiological contaminants is air inhalation. Secondary routes of exposure are ingestion of contaminants from poor hygienic practices and contact and absorption of chemicals through exposed skin. Each of these exposure pathways can be mitigated to a large degree through proper training (e.g., in hazardous materials handling procedures), use of personal protective equipment (e.g., respirators and Tyvek suits), and implementation of engineering controls (e.g., water spray to control fugitive dust emissions).

Site workers actively involved in managing hazardous materials and remediating hazardous waste are properly trained and equipped to handle the hazards associated with such work. The focus of this analysis, therefore, is not on the immediate worker, but on the co-located worker who does not necessarily perform work that results in chemical exposure but by his or her presence at the Site may be exposed to releases that occur.

Air is the only pathway that substantially affects the co-located worker. Air emissions of hazardous chemicals under normal Site operations were modeled to predict potential exposures to the co-located worker. Air releases from point sources (building stacks or vents) and fugitive emissions (contaminated soils) were included in the analysis. All other forms of air release were assumed to be prevented under normal operations.

Calculating Nonradiological Health Effects

The EPA air permitting process under the Clean Air Act does not provide an estimate of potential nonradiological health effects. Instead, EPA considered potential health effects in establishing release limits for regulated chemicals. As long as Site emissions are within the legally permitted emissions, the EPA process assumes that the health and safety of the public is protected.

For the purpose of assessing potential impacts from routine nonradiological emissions, certain assumptions were made to yield reasonable conservative risk estimates (i.e., estimates that tend to overestimate rather than underestimate risk). The co-located worker was assumed to be continually located at the point where the maximum concentrations of contaminants were predicted (i.e., for a Site worker not wearing a respirator). This location was not the same for each chemical modeled, and therefore provides additional conservatism. The individual was assumed not to wear any type of personal protective equipment. Long-term exposures from direct inhalation were calculated because this exposure pathway yielded the maximum contaminant intake (short-term exposures or exposures to lower levels of chemicals or by different intake routes equated to a lower risk to human health). Intake was predicted for a 70-kilogram (154-pound) adult inhaling 20 cubic meters of air per day. The individual was assumed to work 8 hours per day for 50 weeks per year for 30 years as established in EPA's *Risk Assessment Guidance for Superfund* (EPA 1989a).

Exposure to toxic chemicals can cause both cancer and a spectrum of noncarcinogenic toxic effects (ranging from mild headaches or nasal irritation to more serious impacts on the body's organs, nervous system, immune system, and reproductive system). Both carcinogenic and noncarcinogenic health effects were calculated for the co-located worker. Additional details regarding the development of this analysis are presented in Appendix B ("Human Health and Safety").

CALCULATING NONCARCINOGENIC HEALTH EFFECTS. Noncarcinogenic health effects can be expressed as a ratio between actual or modeled concentrations for a particular chemical and the recommended inhalation limit (or "reference dose") for the same chemical as established in EPA's *Risk Assessment Guidance for Superfund* (EPA 1989a) or other standards such as the OSHA 8-hour occupational exposure limit. Reference doses are both chemical- and route-specific. The ratio of the actual or modeled dose and the reference dose is called the "hazard quotient."

Once hazard quotients have been calculated for each hazardous chemical, the quotients can be summed to yield a "hazard index" for the entire mix of toxic chemicals potentially present. Hazard index estimates should be interpreted according to EPA risk assessment guidelines (EPA 1989a).

According to this guidance, if the hazard index is less than or equal to 1.0, the exposure is unlikely to produce adverse toxic effects. and is assumed to be a "negligible risk." If the hazard index exceeds the 1.0 threshold, there is the potential for concern, the degree of concern being a function of the magnitude of the hazard index and whether or not there might be cumulative effects from the multiple chemical emissions. However, health effects from multiple exposures are not considered to be cumulative under the EPA air permitting process. Therefore, the Hazard Index can be a numerical value as large as the number of regulated chemicals (i.e., assuming that each chemical emission is the maximum allowed per the legal limits of the permit). While the hazard index does not provide a statistical probability that a particular chemical mixture at a certain exposure level will cause a particular adverse effect, it can serve as an indicator of the relative potential for causing harm.

CALCULATING CARCINOGENIC HEALTH EFFECTS. Carcinogenic health effects are calculated by multiplying the predicted intake for a particular chemical by the chemical-specific "cancer slope factor" as established by EPA (EPA 1989a). By summing the resulting values for each carcinogenic chemical potentially present, one can estimate an individual's excess lifetime risk of cancer from exposure to the predicted intake.

According to the EPA's *National Contingency Plan* (EPA 1990b) risk assessment guidelines, if the excess lifetime cancer risk is less than 1 in 1 million (10^{-6}), the risk from exposure to the predicted intake of chemicals is "acceptable." If the risk is greater than 1 in 10,000 (10^{-4}), it is above acceptable *National Contingency Plan* guidelines and would be cause for concern requiring mitigation actions (e.g., installing pollution control systems, remediation of a Superfund cleanup site, or more realistic modeling to reduce over-conservatism). If the risk falls in between 1 in 10,000 (10^{-4}) and 1 in 1 million (10^{-6}), there may be cause for concern where additional mitigation or remediation should be considered. It should be noted that the level of concern does not increase linearly as the cancer risk value exceeds the "acceptable" level, since the probability of cancer depends on the specific characteristics of the total mix of chemicals present.

Because cancer slope factors are conservatively estimated by EPA, the carcinogenic risk estimate will generally be an upper bounding estimate. This means that the EPA is reasonably confident that the "true risk" will not exceed the risk estimate derived through the use of this methodology and the "true risk" is likely to be less than predicted.

Noncarcinogenic Health Effects to the Co-Located Worker

Table 4.8-6 presents the hazard quotients and total hazard index for the co-located worker from predicted air releases of toxic chemicals under baseline conditions as defined in Section 4.5.3, "Nonradiological Air Quality." The hazard quotients were taken directly from Table 4.5-5, which compared concentrations to OSHA 8-hour exposure concentration limits.

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Table 4.8-6. Chemical Hazard Index for the Co-Located Worker under Baseline Conditions

Air Pollutants	Hazard Quotient
Criteria Pollutants[1]	
Carbon monoxide	0.1
Lead (quarterly)	3×10^{-12}
Nitrogen dioxide	0.4
PM-10	0.02
Sulfur dioxide	0.5
TSP	0.01
Toxic Pollutants[2]	
Ammonia	0.002
Beryllium	0.002
Carbon tetrachloride	7×10^{-4}
Chlorine	0.008
Chloroform	6×10^{-4}
Dioctyl Phthalate	1×10^{-4}
Hydrochloric acid	7×10^{-4}
Hydrofluoric acid	0.001
Hydrogen sulfide	0.007
Methylene Chloride	5×10^{-6}
Nitric acid	0.007
1,1,1,-Trichloroethane	0.002
Hazard Index[3]	**1.1**

[1]Hazard quotients for criteria pollutants are the ratio of predicted air concentrations to 8-hour OSHA occupational exposure limits.
[2]Hazard quotients for toxic pollutants are the ratio of predicted air concentrations to EPA's inhalation reference dose (EPA 1989a).
[3]Both TSP and PM-10 measure dust concentrations with some overlap; only PM-10 is included in the hazard index because its contribution is more important to health effects.

The hazard index, which slightly exceeds 1.0, suggests potential cause for concern regarding exposure of on-site workers. The primary contributors to this hazard index are criteria pollutants, specifically carbon monoxide, nitrogen dioxide, and sulfur dioxide, which all result from fuel combustion.

Identification of pollutant sources was conducted in a very conservative manner. It was assumed that all emergency generators (which burn diesel) would be in use and that the steam plant would be fueled with #6 fuel oil. At worst, these conditions are only likely to occur for an 8-hour period. Typically, the steam plant is run using primarily electricity (supplied by an external source), and natural gas is used to fuel the steam plant, resulting in much lower emissions of criteria pollutants than was hypothesized for the air modeling analysis. Also, as mentioned earlier, the location of maximum concentration for each chemical is different such that no actual worker is continually present, and actual Site work practices and shifting work duties would lead to less worker risk. For these reasons, exposure of the co-located worker is not thought to be of concern. The hazard index should be used as a basis against which to compare the impacts from the draft Site Closure Plan rather than as an indication of absolute risk.

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Carcinogenic Health Effects to the Co-Located Worker

Potential cancer risk to the co-located worker from modeled air releases of carcinogenic chemicals from the Site is presented in Table 4.8-7. Chemicals of concern were selected based on screening criteria as presented in Section 4.5.3, "Nonradiological Air Quality."

Table 4.8-7. Carcinogenic Health Effects to the Co-Located Worker from Toxic Air Releases under Baseline Conditions

Air Pollutants	Cancer Risk[1]
Ammonia	N/A
Beryllium	2×10^{-6}
Carbon tetrachloride	3×10^{-5}
Chlorine	N/A
Chloroform	3×10^{-5}
Dioctyl Phthalate	N/A
Hydrochloric acid	N/A
Hydrofluoric acid	N/A
Hydrogen sulfide	N/A
Methylene Chloride	1×10^{-6}
Nitric acid	N/A
1,1,1,-Trichloroethane	N/A
Total Cancer Risk	$\mathbf{6 \times 10^{-5}}$

[1]Cancer risk is calculated by multiplying the predicted intake by the EPA cancer slope factor (EPA 1989a), assuming an air intake of 20 m^3/day for a 70 KG adult. N/A = No cancer slope factor available from EPA.

As the table indicates, the excess lifetime cancer risk to the co-located worker is 6×10^{-5} (or 6 in 100,000), which falls within the risk range where there may be cause for concern. Conservative assumptions were used to calculate the health risk from carcinogens to the co-located worker. As mentioned earlier, the location of maximum concentration for each chemical is different such that the no actual worker is continually present, and actual Site work practices and shifting work duties would lead to less worker risk.

Physical Hazards to Site Workers

In addition to potential impacts from nonradiological air emissions, on-site workers are at risk from physical hazards. Injuries can be caused by slips, trips, and falls, vehicle- and equipment-related accidents, improper lifting techniques, heat and cold stress, and a host of other factors. The Site's health and safety program identifies potential physical hazards at the Site and establishes procedures to reduce or eliminate them to the extent possible. Training also plays an important role in minimizing on-the-job injuries.

Reporting requirements for occupational illnesses and injuries provide a means of measuring the effectiveness of the Site's health and safety programs. This data is analyzed in Appendix B ("Human Health and Safety") and is summarized here to represent a "baseline condition" (note: 1995 and 1996 occupational injury and illness data is incomplete since it does not include numerous sub-tier subcontractors; the 1994 base case analyzed in Appendix B provides the most comprehensive analysis of injury and illness potentials associated with Rocky Flats. The number of Site contractor recordable injuries and illnesses has steadily decreased from 1990 through 1994, with no fatalities recorded for workers at the Site since 1987 (i.e., an electrocution). In 1990, 400 cases of Site contractor illness and injury were reported, decreasing to 284 cases in 1994.

The Site injury and illness incidence rate for 1994 was 4.3 recordable cases for every 200,000 hours worked. This compares favorably with the most recent available incidence rate for private industry as provided by the Bureau of Labor Statistics. For 1993, the private industry average incidence rate was 8.5 recordable cases per 200,000 hours worked.

Data from 1994 were used to predict the number of cases under baseline conditions. A total of 253 cases are estimated to occur annually. Based on data from 1990-1994, 19% of recorded cases among contractors are expected to be illnesses, and 81% are expected to be injuries. Approximately 3% of the workforce is affected by injuries and 1% by illnesses. The most common injury is back strain, and the most frequent illness is repeated trauma disorder, which usually results from computer terminal work. An approximate distribution of illnesses among OSHA-defined categories is listed below.

- 49% derived from repeated trauma disorders.
- 33% derived from skin diseases or disorders.
- 7% due to disorders caused by physical agents.
- 5% due to respiratory conditions caused by toxic agents.
- 4% from dust diseases of the lungs.
- 2% from all other occupational illnesses.

4.8.4 Nonradiological Health and Safety–Public

The general public near the Site is potentially exposed to hazardous chemicals through air releases from the Site. Section 4.5.3, "Nonradiological Air Quality," identified sources of nonradiological Site emissions and summarized the concentrations of pollutants to which individuals off-site are potentially exposed. All estimated levels of criteria and toxic air pollutants were found to be below applicable federal and state standards and guidelines, and as discussed in Section 4.8.3 for the co-located worker, the public health and safety is assumed to be adequately protected.

This section characterizes nonradiological health effects from the air pathway to the maximally exposed individual—a hypothetical member of the general public who is assumed to be continually located at the point adjacent to the Site boundary where the maximum air concentrations of contaminants were predicted. As was discussed for the co-located worker, the location of maximum concentration may not be the same for every chemical emission, therefore this method provides a conservative estimate of risk. Air emissions of hazardous chemicals under normal Site operations were modeled to predict potential exposures to such an individual, who was assumed to be a 70-kilogram (154-pound) adult inhaling 20 cubic meters of air per day for 365 days per year for 30 years as established in EPA's *Risk Assessment Guidance for Superfund* (EPA 1989a). Air releases from point sources (building stacks or vents) and fugitive emissions (contaminated soils) were included in the analysis. All other forms of air release were assumed to be prevented under normal operations. Air emissions data and details on air modeling are presented in Section 4.5.3, "Nonradiological Air Quality," and in Appendix B ("Human Health and Safety").

Both carcinogenic and noncarcinogenic health effects from exposure to toxic chemicals were calculated for the maximally exposed individual. Results are presented below. Additional details regarding the development of this analysis are presented in Appendix B, "Human Health and Safety."

Noncarcinogenic Health Effects to the Maximally Exposed Individual

Table 4.8-8 presents the estimated noncarcinogenic risk to the maximally exposed individual from predicted air releases of toxic chemicals under baseline conditions. As described in Section

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4.8.3, "Nonradiological Health and Safety–Worker," if the hazard index is less than or equal to 1.0, the exposure is unlikely to produce adverse toxic effects. If the hazard index exceeds 1.0, there is the potential for concern.

Table 4.8-8. Chemical Hazard Index for the Maximally Exposed Individual under Baseline Conditions

Air Pollutants	Hazard Quotient
Criteria Pollutants[1]	
Carbon monoxide	0.4
Lead (quarterly)	3×10^{-14}
Nitrogen dioxide	0.2
PM-10	0.3
Sulfur dioxide	0.1
TSP	0.4
Toxic Pollutants[2]	
Ammonia	9×10^{-5}
Beryllium	N/A
Carbon tetrachloride	0.005
Chlorine	0.02
Chloroform	N/A
Dioctyl Phthalate	2×10^{-5}
Hydrochloric acid	8×10^{-4}
Hydrofluoric acid	0.004
Hydrogen sulfide	0.02
Methylene chloride	1×10^{-6}
Nitric acid	0.2
1,1,1,-Trichloroethane	2×10^{-5}
Hazard Index[3]	**1.2**

[1]Hazard quotients for criteria pollutants are the ratio of predicted air concentrations to National Ambient Air Quality Standards (40 CFR 50), except for TSP, which compares to Colorado Ambient Air Quality Standards (Colorado Air Quality Control Commission Regulation 14).
[2]Hazard quotients for toxic pollutants are the ratio of predicted air concentrations to EPA's inhalation reference dose (EPA 1989a).
[3]Both TSP and PM-10 measure dust concentrations with some overlap; only PM-10 is included in the hazard index because its contribution to health effects is more important.
N/A = hazard quotients are not applicable for these cancer-causing chemicals.

The hazard index for the maximally exposed individual exceeds 1.0, therefore is potentially of concern. The primary source of pollutants is criteria pollutants. Criteria pollutant concentrations for this analysis are based on modeled Site contributions plus ambient concentrations in the area as measured at locations that vary by pollutant. In most cases, concentrations, and therefore the hazard index, are more representative of background conditions than of the contribution from the Site. Additionally, as discussed in Section 4.8.3, ratios of criteria pollutant concentrations to their standards are not typically summed for the evaluation of air quality. As long as each individual pollutant is below its standard level, air quality is considered acceptable and that the health and safety of the public will be protected. Also, the location of the maximally exposed individual is not always the same. Therefore, the hazard index derived from the sum of hazard quotients is conservative. For these reasons, the hazard index is not indicative in an absolute sense of the degree of risk associated with Site emissions, but rather is useful as a basis against which to compare impacts between *baseline* and *closure* cases.

Carcinogenic Health Effects to the Maximally Exposed Individual

Potential cancer risk to the maximally exposed individual from modeled air releases of carcinogenic chemicals from the Site is presented in Table 4.8-9. Section 4.8.3, "Nonradiological Health and Safety–Worker," provides details on interpreting carcinogenic health effects under baseline conditions.

Table 4.8-9. Carcinogenic Health Effects to the Maximally Exposed Individual from Toxic Air Releases under Baseline Conditions

Air Pollutants	Cancer Risk[1]
Beryllium	1×10^{-10}
Carbon tetrachloride	2×10^{-7}
Chloroform	7×10^{-8}
Methylene chloride	2×10^{-9}
Total Cancer Risk	2×10^{-7}

[1]Cancer risk is calculated by multiplying the predicted intake by the EPA cancer slope factor (EPA 1989a).

As the table indicates, the excess lifetime cancer risk to the maximally exposed individual is 2×10^{-7} (or 2 in 10 million), which is well below the EPA's lower recommended guidance of 10^{-6} (or 1 in 1 million). Total cancer risk from all chemicals combined is below the lower guidance, as is the cancer risk from individual chemicals. Since the hypothetical worst-case scenario indicates negligible risk, it is reasonable to assume virtually no increased risk to the general public.

4.9 Ecological Resources

This section provides an overview of information on biological resources at the Site and serves as a background against which impacts can be assessed. The Site is located slightly below the elevation at which plains grasslands grade abruptly into lower montane (foothills) forests. The topographic diversity and differences in substrate and microclimate associated with this transition zone are reflected in a mosaic of plant and animal communities. The major biotic resources, sensitive habitats, species of special concern, and biodiversity of the Site are discussed below. Risk to ecological resources under baseline conditions is also discussed.

4.9.1 Vegetation

Composition and distribution of plant communities on-site and throughout the region are determined primarily by topography, soil texture, soil moisture, and land use history. Nearly three-fourths of the Site consists of upland surfaces and gentle hillsides that support a diverse association of native grasses, forbs (wildflowers), subshrubs (low shrubs), and cacti typical of prairie environments in the region. Some rockier areas support foothills shrub or pine-grassland communities, while wetter sites along drainages, seeps, and ponds variously support riparian and wetland communities. Remaining portions of the Site include reclaimed grasslands, weedy communities, barren land, and developed areas (e.g., buildings, roads, and parking lots). Acreage and relative extent of the vegetation types and disturbed areas of the Site are presented in Table 4.9-1 (DOE 1992a); their distribution across the Site is depicted in Figure 4.9-1.

Table 4.9-1. Relative Extent of Vegetation Types Identified at the Site

Vegetation Type	Acres	Percentage of Total Site Area
Mesic Mixed Grassland	3,444	53
Xeric Mixed Grassland	1,163	18
Disturbed Area: Developed	634	10
Reclaimed Grassland	569	9
Short Marsh	170	3
Disturbed Area: Annual Grass/Forb	100	2
Short Grassland	84	1
Disturbed Area: Disturbed/Barren Land	76	1
Riparian Shrubland	54	<1
Tall Marsh	40	<1
Riparian Woodland	32	<1
Tall Upland Shrubland	28	<1
Short Upland Shrubland	26	<1
Wet Meadow	16	<1
Ponderosa Pine Woodland	12	<1
Tree Plantings	1	<1

Composition of the major plant communities at the Site is summarized below.

Upland Grassland Communities

A combined area of 4,691 acres (73% of the Site) is dominated by native upland grassland. Although the grassland may appear uniform from a distance, it is complex in terms of species composition and wildlife use. The native grassland at the Site has been divided into three distinct communities: mesic mixed grassland (3,444 acres), xeric mixed grassland (1,163 acres), and short grassland (84 acres) (DOE 1992a, 1994j).

The mesic (moist) and xeric (dry) mixed grasslands are somewhat overlapping and contain several species in common. Among the prominent grasses common to both are blue grama, side-oats grama, prairie junegrass, Canada bluegrass, and little bluestem. The two community types also share an abundance of narrowleaf sedge, plains prickly pear, hedgehog cactus, and yucca (small soapweed). In general, however, the two mixed grassland communities reflect two different topographic and soil conditions.

Mesic mixed grassland generally dominates broad divides, hillsides, and valley floors along drainages. Depending on the specific site, greater soil moisture may result from factors such as subirrigation of the coarse alluvial soils, snow accumulation, northerly aspect, and protection from desiccating (drying) winds. As a result of the increased moisture, the mesic communities may be variously dominated by western wheatgrass, native Kentucky bluegrass, green needlegrass, sleepygrass, and big bluestem in addition to the species listed above. Especially moist sites may also contain switchgrass and yellow Indiangrass. Because of the prominence of tall species in moist areas, portions of the mesic mixed grassland resemble remnants of tallgrass prairie, which has become uncommon in the region as a result of prolonged grazing, agriculture, and development. The protracted protection of the Site from livestock has contributed to the recovery of tallgrass species on-site.

Xeric mixed grassland generally occurs on narrow ridgetops that extend along drainage divides. These areas often are rockier and, because of greater wind-exposure and reduced subirrigation, drier. While sharing some species in common with mesic mixed grassland (particularly the grama grasses and prairie junegrass), this community is typically differentiated by the prevalence of red three-awn, mountain muhly, spike muhly, bottlebrush squirreltail, sand dropseed, and needle-and-thread. Buffalograss, Canby bluegrass, and sheep fescue also may occur throughout the community.

Dry, fine-textured soils along the eastern boundary have been mapped as short grassland (DOE 1992a, 1994j). As the name suggests, the dominant species in this type—buffalograss, blue grama, prairie junegrass, and red three-awn—are low-growing.

The upland grasslands also support three low-growing woody species: fringed sagebrush, broom snakeweed, and a dwarf form of rubber rabbitbrush. Weedy species occur throughout the native grasslands, either as individuals or scattered clumps. Among the more prominent weeds occurring in the native grasslands on-site are musk thistle, great mullein, moth mullein, Klamath-weed, Dalmatian toadflax, desert alyssum, western tansy-mustard, and tall tumble-mustard.

In terms of species richness, ecological diversity, and aesthetics, upland grasslands at the Site are characterized by a wide array of native forbs. The progression of wildflowers during the growing season is both spectacular and indicative of the prolonged protection of most of the Buffer Zone.

Pine Woodland and Upland Shrubland Communities

In some of the western and northwestern portions of the Site, cobbly soils derived from Rocky Flats alluvium support an open woodland of ponderosa pine. The scattered pines represent an eastward extension from the nearby foothills. Species associated with the pines include shrubs (such as wax currant and skunkbrush) and forbs (such as mountain parsley and mountain bladderpod) more typical of the coniferous woodlands that dominate the eastern margin of the Front Range.

Other communities that reflect an eastward extension of foothills environments are the tall upland shrubland and short upland shrubland. These types are collectively referred to in this document as foothills shrubland. Tall upland shrublands are dominated by hawthorn, chokecherry, and wild plum and occur as thickets in mesic but somewhat well-drained sites, particularly along the Rock Creek valley floor and adjacent hillsides. Mountain maple also occurs on some of the rocky hillsides. The presence of these species seems to be controlled primarily by the greater relief, steeper terrain, rockier substrate, and greater abundance of hillside seeps along Rock Creek than the other drainages. In more easterly portions of Rock Creek on-site, where the valley is broader and shallower, the tall shrubs are replaced by lower-growing species, particularly skunkbrush (three leaf sumac), mountain ninebark, and western snowberry.

Riparian, Marsh, and Wet Meadow Communities

Riparian (streamside) trees and shrubs dominate portions of the valley floors in all of the on-site drainage basins. Native trees in riparian woodlands include the plains cottonwood, narrowleaf cottonwood, a hybrid of the two known as lanceleaf cottonwood, peachleaf willow, and box-elder. Non-native trees in riparian corridors include the white cottonwood, white crack willow, and Russian-olive. Associated riparian shrubs include wild rose, golden currant, and western snowberry. Riparian shrublands differ in lacking trees and being dominated by two shrubby species, coyote willow and leadplant, which are low-growing and tend to form extensive, dense thickets.

Tall marsh, short marsh, and wet meadow represent a moisture gradient (from higher to lower). Tall marsh generally occurs along ponds, ditches, and persistent seeps and is variously dominated by cattails or bulrushes; associated forbs include showy milkweed, swamp milkweed, and Canada thistle. Short marsh is more commonly associated with seasonally inundated or

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saturated areas, such as hillside seeps. Prevalent species include low-growing plants such as sedges, rushes, and spike-rush along with hydrophytic (water-loving) forbs such as watercress and speedwell. Wet meadows occupy areas that are intermediate in soil moisture between short marsh and mesic mixed grassland and contain elements of both. Prevalent species may include Kentucky bluegrass, prairie cordgrass, and redtop along with rushes, sedges, and mesophytic (moisture-adapted) forbs.

Additional information on the occurrence and composition of delineated wetlands at the Site is provided in Section 4.9.2, "Wetlands."

Reclaimed or Disturbed Communities

Reclaimed grassland, which occupies 9% of the Site, reflects prior attempts to rehabilitate lands disturbed during Site construction or previous agricultural activities. The most common species are three introduced pasture grasses: smooth brome, intermediate wheatgrass, and crested wheatgrass. Many of the stands are nearly monotypic (one-species) communities. Associated forbs include yellow or white sweetclover, which may have been planted with the grasses, and invasive weeds such as desert alyssum, Dalmatian toadflax, and field bindweed.

Some disturbed areas have not been reclaimed and continue to support sparse or weedy vegetation. Disturbed/barren land includes areas that are essentially devoid of vegetation as a result of prolonged, frequent, or recent disturbance. Other disturbed sites variously support annual grasses (especially cheatgrass and Japanese brome) or annual/biennial forbs. Among the latter are musk thistle, kochia, Russian-thistle, curlycup gumweed, prickly lettuce, shepherds-purse, tall tumble-mustard, western tansy-mustard, flixweed, whitetop, desert alyssum, and cranes-bill. Disturbed areas along roadways are often dominated by dense stands of diffuse knapweed, an invasive species that is rapidly expanding throughout the region.

4.9.2 Wetlands

Wetlands at the Site were delineated in 1994 by the U.S. Army Corps of Engineers. The purpose of this delineation was to prepare a comprehensive inventory of on-site wetlands and to identify wetlands that met the requirement for "jurisdictional wetlands" (i.e., those that are afforded special protection by the Corps of Engineers under Section 404 of the Clean Water Act). The information presented in this section has been drawn from the Corps of Engineers 1994 report (DOE 1994o).

The Corps of Engineers wetland delineation followed the methodology described by the U.S. Fish and Wildlife Service (Cowardin 1979). This methodology integrates information on vegetation, hydrology, geomorphology, and substrate into a classification scheme that recognizes five major wetland systems. Two of these systems were mapped as occurring at the Site. A total of 1,097 separate wetlands were identified during the delineation. These areas occupy a total of 191 acres along the three drainage basins within the Site.

The functional value of wetlands at the Site is linked primarily to erosion control, enhancement of water quality, and maintenance of diverse or areally limited communities. The specific fish and wildlife value of wetlands at the Site is influenced primarily by water regime and landscape position. Stream bottom wetlands provide a wide spectrum of use by both aquatic and terrestrial species, whereas those on slopes (i.e., adjacent to seeps) tend to support more limited seasonal use. Table 4.9-2 presents the number of wetlands and associated areas covered within these drainages (DOE 1994o).

Table 4.9-2. Watershed Wetland Summary

	Slope Wetlands		Stream Bottom Wetlands	
Watershed	Number of Locations	Acres	Number of Locations	Acres
Rock Creek	152	32.17	161	25.37
Woman Creek/Smart Ditch	102	27.15	339	58.19
Walnut Creek	43	8.06	300	40.08
Totals	**297**	**67.38**	**800**	**123.64**

Note: Smart Ditch is an ephemeral drainage with flows that are augmented by irrigation water. It is generally considered to be part of the Woman Creek basin.

Delineated wetlands at the Site are described in more detail below.

Riverine Wetlands

Riverine wetlands are defined as natural or artificial channels that periodically or continuously convey water. Riverine habitats are limited at the Site because of the low frequency and duration of channel flow (DOE 1994o). The on-site streams are ephemeral to intermittent because of two factors. First, the Site is located near the headwaters of the drainages; therefore, upgradient basin size is small. Second, the drainage headwaters are on a nearly flat plain rather than in the nearby mountains. Consequently, the increased precipitation and protracted snowmelt in the foothills do not contribute to channel flows on-site. Instead, runoff from the mountains is intercepted by Coal Creek, a permanent stream flowing northeastward between the Site and the foothills.

Riverine wetlands are best developed on lower reaches of Rock Creek, where the channel is braided and relatively wide. Woman Creek, Walnut Creek, and the upper reaches of Rock Creek support only minor amounts of riverine wetland. Most reaches of these streams and their tributaries contain vegetation (e.g., coyote willow or leadplant) within the active channel and thus are classified as palustrine wetlands, as described below.

Palustrine Wetlands

Unlike riverine wetlands, palustrine (marsh and pond) wetlands may contain vegetation, including woody plants, rooted emergents, and floating or submergent species. Wetlands lacking indicator plants are classified as palustrine wetlands only if they are less than 20 acres in area and 6 feet in depth. Indicator plants include phreatophytes (species adapted to seasonally high water tables, such as cottonwoods) and hydrophytes (species adapted to prolonged conditions of soil saturation or oxygen deficiency, such as cattails).

During the wetland delineation of the Site (DOE 1994o), some of the largest ponds (A-4, B-4, and C-2) were mapped as palustrine wetlands despite having maximum depths greater than 6 feet. This decision was based on the small areal extent of the ponds and the fact that extensive shallow areas result in a mean depth of considerably less than 6 feet. If these ponds had been mapped as lacustrine (i.e., lake) wetlands, the difference would have been one of nomenclature and would have no ecological significance.

Palustrine wetlands at the Site were further divided into slope wetlands and stream bottom wetlands. These units, and the subunits within them, are described below.

STREAM BOTTOM WETLANDS. Stream bottom wetlands (palustrine wetlands associated with stream channels) are the most common type at the Site (Table 4.9-2), accounting for 73% of the total number of wetlands (800 of 1,097) and 65% of the total wetlands area. Because of their association with stream channels, these wetlands are strongly influenced by channel flow, influent seepage from shallow ground water, and channel morphology/substrate. Types of stream bottom wetlands delineated at the Site are described below.

- *Forested wetlands* occur along stream segments in all of the drainages at the Site but are best-developed along Woman Creek. These wetlands, which are equivalent to the riparian woodland vegetation type, are dominated by mature plains cottonwoods and peachleaf willows with a shrubby understory that includes coyote willow, snowberry, and wild rose. Herbaceous species associated with the streamside forest community include western and slender wheatgrasses, switchgrass, Kentucky and Canada bluegrasses, common timothy, field horsetail, scouring-rush, giant goldenrod, field mint, catnip, stinging nettle, and wild licorice.
- *Scrub-shrub wetlands* correspond to the riparian shrubland vegetation type. Dominant species include coyote willow and leadplant with a depauperate (minor) herbaceous understory. Peachleaf willow is commonly present but seldom dominant. Herbaceous species present in low numbers include most of the species associated with temporary wetlands.
- *Herbaceous emergent wetlands* occur along some of the streams, ditches, and pond margins. These wetlands are characterized by a near lack of woody species, although Russian-olive is sometimes present as a non-native invader. Most of the common plants in herbaceous emergent wetlands are the same as described below for slope wetlands. However, some of the species occurring in herbaceous emergent wetlands are restricted to streamsides or pond margins. These include great bulrush, water smartweed, and speedwell. Reed canarygrass and barnyard grass are also present. Narrowleaf and broadleaf cattails are strongly dominant along the margins of some of the impoundments at the Site.

Two additional stream bottom wetland types, aquatic bed wetlands and unconsolidated bed wetlands, were delineated but were not formally inventoried. Aquatic bed wetlands are typically very small and limited to near-shore areas of ponds. Floating aquatic plants such as pondweed and filamentous green algae were reportedly dominant (DOE 1994o). Unconsolidated bed wetlands occur on mudflats or shorelines of ponds or scour holes along streams. These areas either lack vegetation or support sparse stands of barnyard grass, algae, or other plants characteristic of drawdown zones.

<u>SLOPE WETLANDS.</u> A total of 297 (27%) of the jurisdictional wetlands at the Site were classified as slope wetlands. These wetland types are associated with areas where ground water is discharged along hillsides between the alluvial cap and the underlying consolidated material. Although the seeps are fed by shallow aquifers, the discharge is sufficiently persistent to support well-developed stands of wetland vegetation.

Slope wetlands are best-developed in the Rock Creek drainage, which is characterized by a deeper valley with steeper slopes than the other streams on-site. This drainage accounted for over half (152 of 297) of the slope wetlands (Table 4.9-2). The Woman Creek drainage had the second-largest number of slope wetlands (85) but contained the slope wetland with the greatest discharge (Antelope Springs).

Three types of slope wetlands have been defined for the Site based on a gradient of soil moisture (DOE 1994o):

- Saturated wetlands are located at the point of discharge of a seep and are characterized by persistent soil saturation. This wetland unit is equivalent to the short marsh vegetation type at the Site. Most of the saturated wetlands support low-growing graminoids such as baltic rush, Torrey rush, Nebraska sedge, spike-rush, and darkgreen bulrush. Inundated sites, such as along small rivulets or areas of ponding, may support cattails and wetland forbs such as watercress. Other associated forbs include wintercress, willow herb, water horehound, and blue vervain. Areas that support cattails correspond to the tall marsh vegetation type as defined at the Site. Antelope Springs is probably the best example of a saturated slope wetland and tall marsh community at the Site.

- Seasonal wetlands are typically located farther from the water source than saturated wetlands and consequently are consistently saturated only during periods of high discharge (usually spring and early summer). Seasonal wetlands normally do not contain ponded or flowing water. Plants include most of the species listed for saturated wetlands, although they tend to occur in lower abundance. Because of occasionally dry soils, mesophytes such as curly dock, Canada thistle, redtop, and prairie cordgrass are often mingled with the hydrophytes. This unit corresponds to the wet meadow vegetation type at the Site.
- Temporary wetlands are located at the perimeter of saturated or seasonal wetlands and thus are saturated only during brief periods of peak discharge (spring and early summer). Vegetation includes a mixture of prairie species with a wide range of moisture tolerance. Common plants include baltic rush, redtop, western wheatgrass, slender wheatgrass, Canada bluegrass, and Kentucky bluegrass. Clustered field sedge and interior sedge often occur, as do prairie mesophytes such as wild rose, western snowberry, wild licorice, and showy milkweed. Additional species include a variety of prairie grasses and forbs. Most temporary wetlands at the Site correspond to either the wet meadow community type or the mesic mixed grassland type.

Figure 4.9-2 depicts the distribution of wetlands across the Site. Table 4.9-3 shows the relationship between jurisdictional wetland types and the vegetation communities described in Section 4.9.1, "Vegetation."

Table 4.9-3. Wetland Types and Corresponding Vegetation Communities at the Site

Slope Wetlands	Vegetation Communities
Saturated	Short Marsh
Seasonal	Wet Meadow
Temporary	Wet Meadow
Stream Bottom Wetlands	**Vegetation Communities**
Forested	Riparian Woodland
Scrub-Shrub	Riparian Shrubland
Herbaceous Emergent	Tall Marsh and Short Marsh
Aquatic Bed/Unconsolidated Bed	None

4.9.3 Sensitive Habitats

In this document, sensitive habitats are defined as habitats that 1) are subject to federal or state regulation, 2) are limited in areal extent, 3) support wildlife not otherwise found at the Site, or 4) support species of special concern. Using these criteria, five categories of sensitive habitat were identified at the Site: wetlands, riparian areas, foothills shrublands, native grasslands, and ponderosa pine woodlands. The rationale for these designations and brief descriptions of the sensitive habitats are presented below. Acres covered by the constituent habitats and the percentage of the total Site area they occupy are shown in Table 4.9-1.

Wetlands

In addition to their protected status under Section 404 of the Clean Water Act, wetlands meet the other three criteria for defining sensitive habitats at the Site (i.e., they are areally limited, support species not otherwise found on-site, and support species of special concern). Like most native habitats in the Front Range urban corridor, wetlands are increasingly threatened by development pressure. Although jurisdictional wetlands are protected from disturbances or if disturbed, must be adequately mitigated many other wetland areas are not jurisdictional and thus are not protected except by local ordinance in some communities. As a consequence, the scientific and natural heritage value of on-site wetlands is likely to continue to increase over time (DOE 1994o).

In general, wetlands are defined as areas in which saturation or inundation of the substrate is sufficiently protracted to lead to development of specific soil conditions and establishment of specific types of plants. In other words, the persistence of moisture is the primary factor in the creation and maintenance of the community. Habitat types at the Site that meet this definition, in whole or in part, include tall marsh, short marsh, wet meadow, riparian shrubland, and riparian woodland (see Table 4.9-3 above). The latter two types, which differ from the others because of the dominance of woody plants, are discussed separately below.

Tall marsh habitats are generally dominated by cattails or bulrushes. These tall hydrophytes (water-loving species) provide nesting and feeding habitat for red-winged and yellow-headed blackbirds, common yellowthroats, and song sparrows. Some of the tall marsh communities around ponds on-site also support nesting by waterfowl, American coots, and soras (a type of rail) and provide cover for muskrats and black-crowned night-herons. Amphibians such as the Woodhouse's toad, northern leopard frog, and northern chorus frogs all of which breed on-site may also use tall marsh plants along ponds or springs for cover, as may various species of shrews.

Short marsh differs from tall marsh in that it is dominated by low-growing herbaceous species, including rushes, sedges, and hydrophytic forbs (e.g., watercress). These species reflect less frequent inundation and less protracted saturation than required for the tall marsh species. The next drier (less wet) habitat type along this moisture gradient is wet meadow, which typically supports mesophytic (moisture-adapted) grasses and forbs in addition to sedges and rushes.

Because they are dominated by shorter species, short marsh and wet meadow wetlands support few of the wildlife uses described above for tall marsh. They are considered sensitive habitats in this document because they are areally limited on-site and support some native plant species that would not otherwise occur. In addition, some short marsh and wet meadow communities are included in the jurisdictional wetlands previously delineated for the Site (see Section 4.9.2, "Wetlands").

It should be noted that a wetland was created in OU1 (881 Hillside) as mitigation for a wetland that was disturbed during remediation activities (soil excavation and installation of a French drain) at the 881 Hillside. The success of the wetland mitigation is being monitored.

Riparian Areas

Some areas dominated by riparian trees or shrubs are classified as wetlands (see Table 4.9-3 above) and thus afforded special protection under Section 404 of the Clean Water Act. Riparian areas are also considered sensitive habitats because they are areally limited, support a variety of wildlife that would not otherwise be found on-site, and support use by some species of special concern. The riparian areas are the most biologically diverse areas on-site.

Large riparian trees such as cottonwoods and white poplars provide perching or nesting sites for raptors (including the American kestrel, red-tailed hawk, and great horned owl). These trees and smaller peachleaf willows also support a variety of arboreal small birds such as the northern flicker, blue jay, American robin, warbling vireo, yellow warbler, northern oriole, blue grosbeak, and American and lesser goldfinches.

Although dominated by woody species such as coyote willows and leadplant, riparian shrublands are more similar to tall marsh communities than riparian woodlands in several aspects of wildlife use. The riparian shrubs are relatively low-growing and tend to form monotypic (one-species) stands; thus, the compositional and structural diversity of these areas is similar to the tall marsh habitat. However, riparian shrublands are more similar to riparian woodlands in terms of providing cover for deer. Furthermore, the relatively moist conditions at the ground level beneath both the riparian trees and shrubs are favorable for rodents (such as meadow voles and the Preble's meadow jumping mice) that require lusher conditions than those available in most other on-site habitats. As noted in Section 4.9.6 below, the Preble's meadow jumping mouse is a species of special concern.

Foothills Shrublands

Some portions of the Rock Creek drainage on-site support two types of shrub communities tall upland shrubland and short upland shrublands that are nearly absent from the rest of the Site.

Tall upland shrubs, which include hawthorn, chokecherry, and wild plum, occur as thickets along the Rock Creek valley floor and some adjacent hillsides. The presence of these species apparently reflects wetter conditions than those occurring in other parts of the Site, including the Walnut Creek and Woman Creek drainages. The wetter conditions probably result from a combination of greater topographic relief, steeper sideslopes, and coarser soils.

Tall upland shrublands in the Rock Creek drainage are ecologically similar to tributary stream valleys closer to the foothills. Consequently, the tall shrubs support use by a variety of wildlife more normally associated with foothills environments. Examples include the yellow-breasted chat, MacGillivray's warbler, black-headed grosbeak, lazuli bunting, and green-tailed and rufous-sided towhees. The tall shrubs also provide cover for deer. The combination of dense cover, rugged terrain, and a larger prey base appear to make the Rock Creek drainage the portion of the Site where predators such as mountain lions and bobcats are most likely to occur.

Short upland shrublands, dominated by skunkbrush (three-leaf sumac), mountain ninebark, and snowberry, are also more typical of foothills than prairie environments. The short upland shrubs occur in drier, more exposed slopes along the lower portion of the Rock Creek drainage on-site. This type is included as a sensitive habitat because of its limited areal extent and the dominance by plants that do not occur elsewhere on-site. However, the short shrubs provide a less diverse or complex habitat than the tall shrubs, and use by wildlife is therefore less intensive and less varied.

Native Grasslands

Native grassland communities are considered sensitive habitats at the Site primarily because of documented or potential importance to species of special concern. Additionally, they are generally high-quality examples of habitats that have been destroyed by agriculture or development throughout most of the Front Range Urban Corridor.

Native grassland communities at the Site include mesic mixed grassland, xeric mixed grassland, and short grassland. Although all three broad community types are important, areas of tallgrass prairie in portions of the mesic mixed grassland are especially important because of their limited extent in the region. Short grassland is of special concern because of its more limited extent on-site and the potentially important wildlife uses associated with prairie dogs.

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Ponderosa Pine Woodlands

Areas of scattered ponderosa pine in the western and northwestern portions of the Site represent the least extensive native habitat on-site. Although much of the understory beneath the pines is the same as adjacent habitats (mostly mesic or xeric mixed grassland), some associated plants are generally limited to foothills environments.

The term "woodland" is generous; the term "savannah" might be more appropriate because of the low number and density of trees. The pines are worthy of designation as a sensitive habitat because of their limited extent on-site, the limited occurrence of pines so far from the foothills elsewhere in the area, and the presence of some plants and wildlife not otherwise found on-site. Additionally, because of the slow growth of the trees in such marginal conditions, their loss would be difficult to mitigate in a reasonable timeframe.

4.9.4 Wildlife

As in most of the Front Range Urban Corridor, the wildlife at the Site has been greatly influenced by the increase in human use and disturbance over the past 100 years. Most notable have been reductions in the number and diversity of ungulates (hoofed animals) and large predators. However, the habitat diversity of the Site, coupled with protection from grazing and human disturbance across most of the Site, have resulted in relatively rich and intact animal communities. Species that typify the various groups of terrestrial vertebrates and invertebrates at the Site are described below.

Big Game Mammals

The most common big game species at the Site is the mule deer (*Odocoileus hemionus*). Due to their high visibility and their status as year-round residents at the Site, a total of 2,355 individual observations of mule deer were recorded in 1996. Based on data from recent surveys, the current population at the Site is estimated to be approximately 130 to 135 individuals. This estimate is based on a winter deer count, and uses interpolation that takes into account the well-known fact that ungulate herds are routinely underestimated (Wallmo 1981). Site knowledge allows the ecologists to extrapolate observed numbers to estimate population. Elk (*Cervus elephus*) visit the Site on a casual basis, but are not considered resident. A single mule deer/white-tailed deer hybrid buck (male) has been resident at the Site for the past several years, and was again recorded in 1996.

Observations of white-tailed deer (*Odocoileus virginianus*) were more frequent during 1996 (29 observations) than in previous years (RMRS 1996). During the baseline characterization (DOE 1992), no white-tailed deer were recorded, but observations have increased markedly in recent years. During 1996, records of white-tailed deer mingling with mule deer at the Site were common. This species has been expanding its range in recent years to include large portions of Colorado that were previously the sole domain of the mule deer (Werner 1996, pers. comm.). White-tailed deer and mule deer are known to hybridize; therefore, hybridization at the Site may eventually become a management concern. The population trend of this species will bear further observation.

Winter Deer Count Comparison

A sitewide survey conducted on January 13, 1997, for the purpose of obtaining a midwinter population count of big game at the Site, recorded 122 mule deer. Also present at the time of the survey were two white-tailed deer in company with a mule deer herd. Winter surveys such as this are weather dependent, and often, not all deer present at the Site are visible to observers or identifiable by age and sex. It should be noted, however, that the winter count has decreased since 1994, when 164 mule deer were counted in January. The number dropped to 143 mule deer in

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January 1995, and to 118 in January 1996. The 1997 count, however, is comparable to that of 1996.

The age class breakdown continued to indicate a fawn survival rate of approximately one fawn for every two does (1:2). The number of fawns recorded in January 1997 (23), while comparable to January 1996 (20 fawns), was only half that of the previous years (40 in 1994 and 43 in 1995). It should be noted that censuses of mule deer normally yield low counts of actual fawn numbers (Wallmo 1981). To better assess fawn survival, as it relates to the health of the Rocky Flats herd, a spring 1997 deer count will be required. Although opinions vary among authorities on mule deer populations, a fall season fawn-to-adult ratio of 30:70 is apparently ideal for maintaining the herd (Fitzgerald et al. 1994). The winter 1997 count showed 23 percent young-of-the-year (fawns born in June 1996), and some were probably not recorded. Adding spring and fall season deer counts in 1997 may help resolve questions about fawn survival success.

The number of bucks has increased from previous years. The number of does remained somewhat lower than in 1994 but similar to 1996. The 1997 ratio of does (58) to bucks (41), approximately 1.4:1, shows a good balance for a healthy herd. According to Wallmo (1981), a sex ratio of approximately two adult does per one adult buck indicates a very healthy mule deer population. The recent decline in mule deer numbers recorded at the Site may be normal population fluctuation. Should this prove to be a continuing trend, however, it will bear further investigation, especially in light of concern about mule deer populations in general across the western states (Wallmo 1981, pers. comm.; Woodling 1997).

The number of deer present in the BZ (approximately 11 deer/mi^2, on average) remains fairly large, and is attributable to the excellent health of the habitat and the protection afforded by prohibition of hunting within Site boundaries. The absence of accessible roads limits human activity in large portions of the BZ, offering substantial areas of refuge for the Site's mule deer herd. The resulting lack of constant human disturbance in the BZ provides protection from stress, and normally promotes a good fawn survival rate.

Area Use Summary

Monitoring data from 1996 were summarized by season (spring, summer, fall, and winter; Appendix D). Seasonal summaries of mule deer use at the Site reflect the species' strong year-round preference for some locations, and seasonal preference for others. The use patterns reflect two apparent area preference criteria. One preference is for specific seasonal habitat that meets certain survival requirements (e.g., protective cover for new fawns). A second important preference is for secluded areas. Some heavily used areas do not provide unique habitat, but do offer isolation from sources of disturbance.

Mule Deer Spring Area Use — During the spring of 1996, mule deer area use at the Site was the least dispersed compared to the other seasons, and mirrored longer-term use patterns discussed in the 1995 annual report (RMRS 1996). Snow-free south-facing hillsides were most preferred, as were locations providing the best refuge and thermal cover from residual winter storms that are common during March and April. Areas with the heaviest mule deer use were upper Rock Creek, the lower Rock Creek shrublands unit, the area encompassing the Antelope Spring and Apple Orchard Spring complex, and the upper Smart Ditch drainage basin. Several locations in xeric tallgrass prairie community were also frequent use areas when the weather was not severe.

Mule Deer Summer Area Use — Summer area use patterns in 1996 also mirrored those found in the four-year summaries presented in the 1995 annual report (RMRS 1996). Mule deer use during the summer was quite dispersed, with high use recorded in upper Rock Creek and similar portions of Woman Creek, Walnut Creek, and Smart Ditch. Fawning occurs at the start of the summer season (June), and by the end of summer (August), the fawns are gaining independence. Some areas of limited extent show evidence of heavy use by does with fawns or by groups of bucks.

Does with dependent fawns show a strong preference for areas with tall upland shrubland and riparian woodland complex habitats, such as those found in upper Rock Creek and along the bottomland areas of the Woman Creek and Smart Ditch drainages. Adequate cover to conceal young, along with isolation and security, are requirements for fawning habitat (WGFD 1985). For example, Rock Creek's tall upland shrubland is ideal fawning habitat.

Bucks are drawn to secluded areas with ample shade cover during this season. These areas include upper Rock Creek, the lower Rock Creek shrubland units, and the Smart Ditch drainage basin. Mature bucks are seldom found in the company of does with young during this season.

Mule Deer Fall Area Use — Mule deer use patterns during the fall of 1996 were similar in location and extent to the summer use patterns, and mirrored the longer-term summary presented in the 1995 annual report (RMRS 1996). The areas of heavy use were somewhat more extensive than in the summer, but very similar to previous years. The most concentrated fall use again was within the upper Rock Creek drainage, the Antelope Spring and Apple Orchard Spring complex, and the Smart Ditch bottomland areas occupied by riparian woodland complex. An additional heavy use area during this season was the riparian woodland complex of the A-Ponds. Certain areas occupied by xeric tallgrass prairie were also areas of high use, reflecting the tendency of the species to concentrate in these areas during the November breeding season (the rut). During the rut, large mixed-sex groups of mule deer were observed frequently in the open grasslands, often at the same location for several days at a time.

Mule Deer Winter Area Use — Winter mule deer area use at the Site continued to be somewhat less concentrated than spring use, but more concentrated than summer and fall. As in the other seasons, the most preferred locations are upper Rock Creek, the Antelope Spring and Apple Orchard Spring complex, and the Woman Creek and Smart Ditch bottomlands. Additionally, a pattern of use on south- and southeast-facing mesic grassland hillsides was evident. Some winter use patterns clearly reflected the thermal advantages provided by the preferred areas. Other winter use areas provide better quality, or more available forage, with reduced procurement effort (i.e., a better energy return for the effort). Upper Rock Creek, for example, provides refuge from the frigid northwest winter winds. South- and southeast-facing slopes provide the greatest incident thermal energy, as well as the best snow-free forage areas. Even as early as late January, many of the early forbs and grasses on these slopes are greening for spring growth, and provide good early-season forage.

Overall Annual Area Use — Figure 3-2 provides an area use preference summary for all seasons of 1996. When compared to the overall use summary for all seasons over several years, shown in the 1995 annual report, the use patterns remain virtually identical.

Area use data are an important tool used by Site ecologists to help project planners schedule disruptive activities so impacts on essential areas at critical times are minimized. Changes in scheduling may be all that is necessary to avoid unnecessary impacts to important species.

Mule Deer Habitat Use Summary

Mule deer habitat use concentration varied somewhat by season (Table 3-3). In the spring, 75 percent of the mule deer observed were in native grasslands (i.e., xeric mixed grassland and mesic mixed grassland), and 17 percent were observed in tall upland shrubland. In the summer, the concentration shifted away from the native grasslands (50 percent) to the woody communities (24 percent in upland shrublands and 14 percent in riparian woodland/shrubland). In the fall, the habitat use concentration shifted back to the native grasslands (69 percent) and upland shrublands (16 percent). Winter habitat use was virtually identical to fall (69 percent native grassland and 13 percent upland shrubland).

Elk and White-Tailed Deer Area Use Summary

Few data are available on elk and white-tailed deer habitat preferences at the Site, but the higher number of white-tailed deer observations during 1996 indicates their continued willingness to abandon their normally preferred shrubland habitat to join the mule deer in the open grasslands. Habitat use summaries (Table 3-3) indicate that white-tailed deer use shrublands and grasslands almost equally. The majority of the white-tailed deer observations were of individuals in company with large or small groups of mule deer. Of interest is the fact that the white-tailed deer have extended their presence at the Site, from an initial concentration in lower Smart Ditch to an occasional presence near the A-Ponds and middle Rock Creek. Elk sign was observed in Rock Creek, and a single bull elk was observed in a wetland area in Smart Ditch during 1996.

Mid-Size Mammals

Desert cottontails (*Sylvilagus audubonii*) were the most commonly observed lagomorphs (rabbits and hares) at the Site during 1996 (141 observations). As in previous years, desert cottontails inhabited disturbed areas, scrap storage areas, trailer yards, conex storage areas, rip-rap areas, and other areas affording cover. White-tailed jackrabbits (*Lepus townsendii*) and black-tailed jackrabbits (*Lepus californicus*) have been recorded at the Site, but individuals of both species are seldom observed, and only tracks were recorded during 1996. Jackrabbits also were found near disturbed areas, but were most frequently observed near the aggregate mines at the Site. Table 3-4 provides a seasonal habitat use summary for these species. A complete 1996 data summary is provided in Appendix C. The 1996 area use data summary is provided in Appendix D.

Muskrats (*Ondatra zibethicus*) were observed in impoundments (ponds) and tall marsh (in the SID) during 1996. Populations of this species are difficult to estimate without a heavy trapping regimen, but 20 observations in 1996 confirm the continued presence of the species in appropriate habitat. Table 3-4 summarizes seasonal habitat use by this species.

Signs of porcupines (*Erethizon dorsatum*) were observed on 3 occasions in 1996, and one actual observation was recorded. All were within areas of the Rock Creek drainage. Their preferred forage species are hawthorn (*Crataegus sp.*), choke-cherry (*Prunus virginiana*), and ponderosa pine (*Pinus ponderosa*), all of which are most abundant in upper Rock Creek. Table 3-4 summarizes seasonal habitat use by this species.

Eastern fox squirrels (*Sciurus niger*) are uncommon at RFETS due to limited habitat, and most probably, the abundance of predators. One individual was recorded in upper Rock Creek during 1996.

Prairie dogs were once established in several colonies at the Site, but had not repopulated by the end of 1996. Prairie dog populations in the vicinity have not rebounded from the regional die-off caused by the plague epizootic in 1994.

Carnivores

The most abundant carnivore species at the Site is the coyote (*Canis latrans*) (158 observations in 1996), and the next most abundant is the raccoon (*Procyon lotor*) (18 observations). The coyote population declined in late 1994, probably due to canine distemper, which swept through the local area, but the population rebounded to normal in 1996. Four different coyote whelping dens were recorded during 1996, confirming that the coyote population has returned to normal after the distemper outbreak. Coyotes were found in all habitats, but were most visible in marshlands and grasslands. Areas frequented by carnivores are shown on Figure 3-3. Table 3-5 provides a seasonal habitat use summary for 1996. A complete 1996 data summary for these species is provided in Appendix C. The 1996 area use data summary is provided in Appendix D.

Raccoons are most frequently documented from tracks or through small-mammal trapping. Because of their penchant for robbing bait from traps set for small mammal studies, raccoons are often intentionally trapped in live-traps set along small-mammal traplines and are relocated to other locations on the Site to prevent their continual interference in small-mammal studies.. A total of 17 individuals were observed during 1996. Observations were in both the Industrial Area (IA), where they frequented areas with food refuse, and in the BZ, near riparian channels and pond margins. Locations of raccoon observations are shown on Figure 3-3. Table 3-5 provides a seasonal habitat use summary for 1996.

Other carnivores observed at the Site during 1996 included striped skunks (*Mephitis mephitis*), gray foxes (*Urocyon cinereoargenteus*), and mink (*Mustela vision*). Black bears (*Ursus americanus*) were recorded for the first time in 1996. Area use by these carnivores is illustrated in Figure 3-3. Most sightings of these carnivores are fortuitous or are made during night surveys, or their presence is indicated by observed tracks or sign (see Table 3-5 for habitat use in 1996).

Carnivores are the top species in the mammalian food chain, and trends in their populations are an indicator of the ecological health of an area. The top carnivores in an ecosystem must have a large, healthy population of prey species upon which to subsist. Reduced numbers of prey species are normally reflected in reduced numbers of carnivores.

Waterfowl (Ducks, Geese, and Shorebirds)

The majority (51 to 98 percent, seasonally) of the 48 species of waterfowl and other shorebirds observed at the Site were concentrated around the impoundments (ponds) (Table 3-6). Area use varies somewhat between the fall/winter and spring/summer seasons. Fall/winter area use was highly concentrated on the major impoundments at the Site, while spring/summer use was more dispersed. Some observations during the breeding season occurred along creeks, in ditch and creek pools, and in greening grasslands. Of this group, 14 species have been documented as breeders or suspected breeders at the Site. The most recent was the ruddy duck, which not only was first recorded at the Site during 1996, but was also confirmed as breeding at Pond D-2.

Most waterfowl and shorebirds were observed on the large impoundments at the Site. Diving ducks, such as buffleheads (*Bucephala albeola*), ring-necked ducks (*Aytha collaris*), redheads (*Aytha americana*), and lesser scaup (*Athya affinis*), were most commonly observed in the deeper ponds (A-3, A-4, B-5, and C-2). Species found more generally in shallow waters of the deeper ponds and in the shallower ponds included blue-winged teal (*Anas discors*), mallards (*Anas platyrhynchos*), cinnamon teal (*Anas cyanoptera*), and gadwall (*Anas strepta*). Puddle-ducks, primarily mallards, were also observed in pools, at seeps, and along creeks. Great blue herons (*Ardea herodias*) were observed on impoundment mudflats and in ditches, short marshland, and wet meadows.

The most common waterfowl at the Site during 1996 were mallards (667 observations) and Canada geese (*Branta canadensis*) (335 observations). The most common wading bird at the Site was the great blue heron (25 observations). Proportionally, these observations are comparable to previous years (DOE 1992; EG&G 1995a; RMRS 1996).

In addition to the species listed above, there were several common summer season residents. These species included double-crested cormorants (*Phalacrocorax auritus*) (20 observations in summer 1996), pied-billed grebes (*Podilymbus podiceps*) (277 observations for the year), American coots (*Fulcia americana*) (366 observations for the year), and green-winged teal (*Anas*

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crecca) (137 observations for the year). New waterfowl and wading bird species recorded at the Site in 1996 included the white-faced ibis, a special-concern species, and the ruddy duck (*Oxyura jamaciensis*).

Several waterfowl species raised young at the Site during 1996. Brood counts confirmed nesting by pied-billed grebes, American coots, mallards, green-winged teal, blue-winged teal, cinnamon teal, and ruddy ducks. Black-crowned night herons (*Nycticorax nycticorax*), though not numerous at the Site (11 observations), were suspected to have bred at Pond D-2. Breeding by this species at this location has been confirmed in previous years (EG&G 1995a).

Raptors

All raptors with appropriate habitat and range for the Site's vicinity in Colorado have been recorded at the Site (Andrews and Righter 1992). Although the raptor species using the Site vary between the spring/summer and fall/winter seasons, the areas of frequent use during these seasons were very similar. Figure 3-4 illustrates the areas of high use for raptors at the Site. The use concentrations throughout the year are highest in the Rock Creek shrublands, the riparian corridors of the three main drainages of the Site, and around the ponds. Since these are the areas of concentration for prey species (small mammals, songbirds, and waterfowl), higher use of these areas by the avian predators is to be expected. A complete 1996 data summary is provided in Appendix C. The 1996 area use data summary is provided in Appendix D.

Observations of red-tailed hawks (*Buteo jamaicensis*) declined somewhat, with 86 observations in 1996, compared to 100 in 1995 (RMRS 1996). It should be noted that these numbers include all observations (survey data and fortuitous observations) inducing some observational bias. However, Site knowledge, historical data, and professional judgment are used in interpreting the data. The decline in red-tailed hawk observations may be due to the generally low numbers of over-wintering hawks at the Site during recent years. The depressed prairie dog prey base in the larger vicinity has caused a corresponding reduction of raptors in the area since 1994 (RMRS 1996; EG&G 1995a).

Great horned owls (*Bubo virginianus*), were observed somewhat more frequently in 1996 than in 1995; however, this increase is largely due to numerous observations of flightless owlets at two nest locations. American kestrels (*Falco sparverius*) continued to be common at the Site, with 51 observations in 1996. Northern harriers (*Circus cyaneus*) were less commonly observed in 1996 (18 observations). One pair of Swainson's hawks (*Buteo swainsoni*) nested at the Site, successfully fledging one young bird. Golden eagles (*Aquila chrysaetos*), while observed at the Site year-round, were not numerous (12 observations in 1996). Prairie falcons (*Falco mexicanus*) were recorded on three occasions (four individuals).

Only three Ferruginous hawks were observed in the BZ, and one in the Extended Observation Area (EA), down from seven in the BZ and 40 in the EA in 1993 (EG&G 1994). The number of ferruginous hawks recorded in the vicinity has declined since the prairie dog die-off of 1994. Rough-legged hawk (*Buteo lagopus*) observations declined from 21 in 1995 to 8 in 1996. The lower number of their preferred prey species (prairie dogs) is suspected to be the cause.

Other raptor species recorded at the Site in 1996 include short-eared owls (*Asio flammeus*), long-eared owls (*Asio otus*), a sharp-shinned hawk (*Accipiter striatus*), an American peregrine falcon, a merlin (*Falco columbarius*), Cooper's hawks (*Accipiter cooperii*), and turkey vultures (*Cathartes aura*). Several of these are special-concern species. Raptors that nested at the Site during 1996 included great horned owls, red-tailed hawks, and Swainson's hawks.

Habitat use by season is summarized in Table 3-7. The majority of raptor species use woodlands or tall upland shrublands for nesting and roosting habitat, and forage in all habitats.

Falcons generally forage where songbirds or waterfowl are abundant (woodlands, shrublands, and impoundments), while buteos (broad-winged hawks) more commonly forage in the grasslands and wetlands.

Migratory Birds

Relative Abundance

Assessment of relative abundance (number of individuals observed per unit time in a given habitat) is a qualitative means of determining species densities in various habitats. Table 3-9 summarizes bird distribution by habitat, based on relative abundance comparisons from migratory bird surveys, relative abundance surveys, sitewide surveys, project-specific surveys, and fortuitous observations. This summary table shows a running tally of species recorded at the Site since 1991, and presents relative abundance in appropriate habitats for each species. The table does not contain estimates of total population for each species inhabiting the Site. Some species are very habitat specific, while others are virtually ubiquitous.

Evaluation of habitat use by birds, as indicated by cumulative combined records from all observation methods since 1991, yields somewhat different total species numbers for the different habitats than the species richness data from bird surveys only, as discussed in Section 3.2.3. Based on all combined data, bird species richness in the major habitats at the Site is 94 species in grasslands, 89 species in tall upland shrubland, 80 species in riparian shrubland, 111 species in riparian woodland complex, 111 species in wetlands, and 50 species in disturbed habitats (Table 3-9).

General Observations

Several migratory bird species new to the Site were recorded during 1996. These sightings were made during relative abundance surveys and bird surveys, or were recorded as fortuitous sightings. New waterfowl included the ruddy duck and the white-faced ibis (*Plegadis chihi*), a species of special concern. The new passerine (songbird) species are the mountain chickadee (*Parus gambei*), the northern mockingbird (*Mimus polyglottos*), the brown thrasher (*Toxostoma rufum*), the American redstart (*Steptophaga ruticilla*), the snow bunting (*Plectrophenax nivalis*), the fox sparrow (*Passerella iliaca*), the purple finch (*Carpodacus purpureus*), the semipalmated sandpiper (*Calidris pusilla*), and the field sparrow (*Spizella pusilla*).

As a result of breeding bird surveys, relative abundance surveys, and fortuitous observations, the list of confirmed and suspected breeding bird species continued to grow in 1996, to include 187 species. Based on known ranges and typical habitat for Colorado bird species outlined by Andrews and Righter (1992), 134 of the species reported at the Site are within their primary ranges, 45 are in secondary range, and 7 are accidental. There is a potential for an additional 39 species to occur, but range maps for these species show the Site at the edge of their ranges.

Confirmed breeding species are those species that have been observed building nests, tending eggs, or tending young, or for which young, flightless nestlings have been observed. Suspected breeding species are those that have been observed carrying nesting material, food, or other such indicators of breeding activity, without visual confirmation of the presence of a nest or young. The current list of breeding bird species now includes 73 species believed to breed on the Site. Among the 100 species of neotropical migrants known to use the Site, 45 are confirmed or suspected breeders at the Site.

Migratory Bird Survey Summaries

Five years of migratory bird survey data, gathered along 20 permanent transects at the Site, were evaluated for trends in species richness (number of species) by habitat, and for bird densities (individuals per hectare) for each of seven habitats. Species richness and densities were summarized by season. Data collected during 1996 were compared to previously reported data (DOE 1992; EG&G 1994, 1995a; RMRS 1996) to examine trends in these parameters. Results for the five years' data for the summer breeding season (the month of June) and for the winter season (December, January, February) are discussed below.

Bird Species Richness Trends

In interpreting the following discussion, it is necessary to understand that a sufficient sample size to allow statistical adequacy (a test of power) for data analyses will not be reached until several more years of data have been collected. Bird populations are subject to natural variations from year to year, depending on local weather and forage conditions. Species as mobile as birds can easily shift residential area use in response to forage availability, range conditions, and severe weather. Short-term changes in populations and species presence can be expected from year to year. A Pearsons correlation run on the species richness data indicated that, except in riparian woodland, the trends presented were not statistically significant (showed no actual change).

Species richness increased slightly in all habitats over the 5-year data collection period (Table 3-10, Figure 3-5). The increase in species richness in riparian woodland during the breeding season was statistically significant, showing an apparent actual increase in species numbers. Apparent increases in other habitats were the result of normal fluctuations. Some of this increase may be due to increased familiarity of the field personnel with the bird species typical of the Site, resulting in higher identification accuracy of obscured birds and bird vocalizations. Individually, most habitats reflect this trend in both the winter season and the June breeding season (Figure 3-6 to 3-12). The exceptions appear in wetlands (Figure 3-6) and leadplant-dominated riparian shrublands (*Amorpha fruticosa*) (Figure 3-8), where the species richness has declined slightly, and in xeric mixed grasslands, where richness has remained unchanged (Figure 3-11).

Neotropical migratory birds are migratory species that travel to Central and South America (the neotropics) to over-winter, and return to North America to breed. These species have been of interest to ornithologists throughout the Western Hemisphere because most species populations have declined in numbers. Many neotropical species are watch-listed by ornithological groups. Neotropical bird species richness at the Site has fluctuated from year to year, with a slight downward trend in numbers of species during the five years of monitoring. Figure 3-13 illustrates species richness of neotropical migrants during the breeding season (June) since 1991. The downward trend may reflect the overall decline of this group regionally (Carter 1996, pers. comm.). Groups such as the Colorado Bird Observatory have been collaborating with South American scientists to track trends and monitor breeding success of species in this group.

Because the apparent decline in the number of wetland species during the breeding season was of some concern, data records for the remaining summer surveys were reviewed to determine whether this trend appeared genuine (Table 3-10). This supplemental data review included fortuitous observations and relative abundance survey data, as well as migratory bird survey data. Findings of this additional review indicated that, while some previously recorded species were not observed on the 1996 breeding season transects, most of these species were actually still present at the Site, but were not observed on the surveys performed in June. Those species that were not observed at all were generally in the category of rare to the Site, and records of these species are not consistent from year to year.

Species richness in winter is typically low when compared to summer (see Appendix E). The characteristic winter species assemblage changes somewhat from year to year with additions or losses of recorded species in most habitats. Occasionally, severe winter weather drives birds into deep cover where they cannot be observed, or sometimes causes them to move temporarily to milder off-site locations. Analysis of winter conditions is hampered by low numbers of observations. The assemblage in riparian woodland, however, is normally characterized by

American tree sparrows (*Spizella arborea*), great-horned owls (*Bubo virginianus*), and northern flickers (*Colaptes auratus*). Tall upland shrublands are normally characterized by black-billed magpies (*Pica pica*), and black-capped chickadees (*Parus atricapillus*).

The greatest richness in summer bird assemblages appears in woodland and tall upland shrubland habitats (Table 3-10). These two woody habitats have the greatest annual maximum and mean species richness of all the habitats surveyed. Grassland habitats, although they exhibit somewhat lower species richness, support very different species assemblages (Appendix E). Since multi-strata woody vegetation types provide a greater number of niches, the greater species richness is expected. It should also be noted that the linear character of these woody habitats tends to provide a large ecotonal zone that is attractive to both woodland/shrubland species and grassland species. Thus, numerous grassland species may also be observed at the edges of the woody habitats. The sitewide bird species richness, including species recorded in grasslands, woody vegetation types and wetlands, includes 185 different species (Table 3-9).

To better understand the differences and similarities of bird species assemblages in different habitats at the Site, a similarity index (Simple Matching Coefficient) was prepared to allow comparison of the major habitat types. This particular index compares the co-occurrence of bird species between habitats for the 5-year observation period, and also gives weight to species that were absent when compared to the bird species list for all habitats (Table 3-9). The comparisons were made on a habitat pair-wise basis (e.g., grassland habitat in 1991 versus woodland habitat in 1993). These index numbers represent the degree of similarity between each species set. An index of 1.0 demonstrates that the lists are identical, while low numbers (e.g., 0.38) demonstrate a low degree of similarity.

This comparison revealed that woodland/shrubland habitats support slightly different assemblages of birds than wetlands and grasslands, and that species assemblages in grasslands and wetlands are more similar to each other than they are to the woodland/shrubland assemblages. This is expected, because of the landscape layout of these habitats. Wetlands are most often long, narrow strips or patches set into surrounding grasslands. Ecotonal areas between these two habitats are often indistinct, and both habitats are often sampled together along these transects. In general, grassland species are common along wetland edges, but species that prefer woody habitat are more niche specific, and are less likely to spend time in less favorable habitat. Table 3-11 presents a similarity index analysis that compares grassland, woodland/shrubland, and wetland habitats on an annual basis.

Bird Density Trends

Several typical species for each monitored habitat were selected for bird density trend analysis. Standard deviations of density calculations (Table 3-12) indicate that these trends are not significant, but they do provide a measure of the health of migratory bird populations at the Site. Table 3-12 presents the densities (individuals per hectare) of these selected species over time. Species were selected based on their overall density in each habitat type and/or their uniqueness to a particular habitat (indicator species). Trends of undesirable species, specifically the European starling (*Sternus vulgaris*) and the brown-headed cowbird (*Molothrus ater*) are also described where appropriate. These species are considered undesirable because of competition with native species and nest parasitism, respectively.

Wetlands are represented by the red-winged blackbird (*Agelaius phoenicues*), song sparrow (*Melospiza melodia*), common yellowthroat (*Geothylpis trichas*), and common snipe (*Gallinago gallinago*). Overall, densities of these species in wetland areas are increasing (Table 3-13). Changes in densities of less desirable species are insignificant.

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Riparian woodland habitats are represented by the northern oriole (*Icterus glabula*), American goldfinch (*Carduelis tristis*), house finch (*Carpodacus mexicanus*), and yellow warbler (*Dendroica petchia*). Northern oriole densities are increasing, but densities of the other three species have decreased (Table 3-12). The density of European starlings is increasing in riparian woodland areas. The density of brown-headed cowbirds is relatively stable over time.

Leadplant-dominated shrub habitats are represented by the vesper sparrow, northern oriole, and mourning dove. The overall trend of these selected species is increasing densities (Table 3-12). The density of starlings is also increasing, whereas brown-headed cowbirds are rare.

Tall upland shrubland habitat is represented by song sparrows, rufous-sided towhees, black-billed magpies, yellow-breasted chats, and black-capped chickadees. Black-capped chickadees appeared only recently in this habitat; during the first two years, none was observed, then they appeared and have been increasing in density. The overall densities of the selected species in this habitat show an increase. Densities of yellow-breasted chats are stable over time.

Mesic mixed grasslands are represented by the vesper sparrow, the house finch, the western meadowlark, and the grasshopper sparrow. The densities of house finches and meadowlarks are increasing, whereas vesper sparrow densities are declining. The density of grasshopper sparrows is increasing.

Xeric mixed grasslands are represented by grasshopper sparrows, vesper sparrows, western meadowlarks, and mourning doves. These selected species are showing an increase in densities over time, with the densities of meadowlarks and mourning doves increasing only slightly. There is a general trend of increased grasshopper sparrow densities in grassland habitats across the Site.

Reclaimed grasslands are represented by the western meadowlark, the vesper sparrow, and the grasshopper sparrow. The overall density trend for these selected species is steady, but the density of grasshopper sparrows is increasing.

Reptiles and Amphibians

As is typical for the region, reptiles and amphibians are not well represented at the Site. The most common reptiles are the bullsnake, yellow-bellied racer, garter snake, and prairie rattlesnake. All of these species occur in the open grassland habitats that dominate the Site, although garter snakes are frequently observed near (or in) water. Other reptiles observed include the short-horned lizard in open grasslands, eastern fence lizard in rocky shrublands, and western painted turtle in ponds.

By far the most abundant and widespread amphibian at the Site is the northern chorus frog, which breeds on-site in virtually every stream, pond, ditch, or other area where surface water persists through the spring and early summer. The northern leopard frog is less common; this species is completely aquatic and requires permanent water such as some of the ponds provide. Woodhouse's toad breeds in ponds and streams at the Site but may wander considerable distances from water in search of insect prey. The plains spadefoot requires the least persistent water of any of the amphibians at the Site. This species breeds in seasonally wet areas and, like the northern chorus frog and Woodhouse's toad, spends most of the year in the mud.

Another amphibian that occurs at the Site is the tiger salamander. Aquatic larvae of this species have been documented in several of the ponds on-site. During late summer, the black-and-yellow adults may move considerable distances across land, taking shelter in animal burrows during the day to avoid desiccation.

Herptiles (Reptiles and Amphibians)

Herptile species observed during 1996 included the bullfrog (*Rana catesbeiana*), boreal chorus frogs (*Pseudacris triseriatus maculata*), northern leopard frog (*Rana pipiens*), tiger salamanders (*Ambystoma tigrinum*), western painted turtles (*Chrysemys picta*), eastern short-horned lizards, the western plains garter snake (*Thamnophis radix*), the red-sided garter snake (*Thamnophis sirtalis*), and the prairie rattlesnake (*Crotalus viridis*).

Terrestrial Invertebrates

Four classes of arthropods—millipedes, pill bugs, spiders, and insects—have been captured during sweep-netting and pitfall-trapping surveys in conjunction with ecological evaluations at the Site. Of these, insects are the most abundant and taxonomically diverse group. Terrestrial insects captured during Site surveys have included representatives of ten major families. In general, leafhoppers (a plant-eating group) were the most abundant insects. Other groups of plant-eaters (herbivores) included treehoppers, spittle bugs, seed bugs, leaf bugs, leaf beetles, grasshoppers, and crickets. The other two groups captured were ladybird beetles (which feed on smaller insects) and ants (which consume both plant and animal matter). Common insects such as butterflies, moths, bees, and wasps are also present on-site but have not been specifically documented during ecological investigations. Although not as diverse as the insects, true spiders are the second most abundant group overall in terms of number of captures during Site investigations. Millipedes and pill bugs were captured in smaller numbers during the previous studies.

Invertebrates provide an important prey base for many species of reptiles, birds, and small mammals. Grasshoppers are probably the most important invertebrates in the terrestrial food web because of their abundance, large size, and tendency to occur on the foliage of plants where they are easily detected and captured.

4.9.5 Aquatic Fauna

Detention ponds, former agricultural ponds, natural drainages, and ditches provide a limited variety of aquatic habitat at the Site. The composition and structure of on-site aquatic systems are strongly influenced by widely and suddenly fluctuating water levels in many of the ponds and by intermittent flows in the streams and ditches. The fish community is further limited by isolation of the Site; the presence of some fish species is completely dependent on intentional introductions. Aquatic communities at the Site are summarized below.

Macroinvertebrates

Across most of the Site, aquatic macroinvertebrate communities in streams and ditches are limited by low and irregular flows, except for a few isolated pools, and by predominantly fine-textured sediments. The most abundant and widespread groups overall in stream communities are the larvae of true flies and mayflies. The most common true flies are blackflies and midges. Other aquatic invertebrates include caddisflies, craneflies, predatory damselfly larvae, and two non-insect groups: snails and amphipods (sideswimmers).

Pond habitats provide a more reliable water source, but the fine sediments and (in many ponds) relative lack of aquatic plants limit macroinvertebrate diversity. Most of the communities are strongly dominated by midges and aquatic earthworms. Ponds with well-developed aquatic plants along the margins support nektonic (free-swimming) aquatic insects such as water striders and water boatmen. Predatory dragonfly nymphs are present in some of the ponds, as are crayfish.

Large macroinvertebrates such as crayfish and snails are potentially important as prey for species such as largemouth bass, mallards, great blue herons, and raccoons.

Fish

As with macroinvertebrates, low and intermittent flows along most stream reaches within the Site greatly limit the presence of fish at the Site. Species captured during sampling of streams have included the fathead minnow, creek chub, stoneroller, and green sunfish. Of these, the creek chub is the most tolerant of poor water conditions and reportedly inhabits virtually all streams within its range that are capable of supporting fish (McClane 1978). Creek chubs feed on a variety of small invertebrate prey; fathead minnows feed primarily on plankton; stonerollers consume both plant and invertebrate prey; and green sunfish feed on nektonic (free-swimming) invertebrates and smaller fish.

Fish communities in ponds are highly influenced by the presence of suitable substrates, aquatic vegetation, and persistence of water as well as by historical introductions. Species present include the four species listed above, plus the golden shiner, white sucker, and largemouth bass. Golden shiners feed on a variety of small prey and algae and are themselves important prey for larger fish or piscivorous (fish-eating) birds because of the large populations they attain and their relatively large size. White suckers, which are relatively tolerant of pollution, siltation, and low oxygen, feed on insect larvae and algae. Largemouth bass caught in some of the ponds include large specimens at the top of the aquatic food web, aside from piscivorous species such as double-crested cormorants and great blue herons.

4.9.6 Species of Special Concern

A variety of species of special concern have been documented at the Site, and additional species of special concern are potentially present (based on the availability of suitable habitat). In this document, species of special concern include plants or animals that are federally listed as threatened or endangered, candidates for listing as threatened or endangered, or Colorado species of special concern. The latter designation is used by the Colorado Division of Wildlife for animals and the Colorado Natural Heritage Foundation for plants. The Colorado Division of Wildlife also lists wildlife species considered threatened and endangered in the state.

The Site Buffer Zone is an island of relatively undisturbed habitat within a region where most other land has been heavily grazed, cultivated, developed, or subjected to other impacts associated with intensive human activity. The result is that more species of special concern are present, or potentially could occur within the Site, than in most of the surrounding area. Table 4.9-4 contains a summary of the species of special concern at the Site.

Table 4.9-4. Special Concern Species Search-List

Federal Endangered Species Known to Occur at Rocky Flats	
Birds	American Peregrine Falcon (*Falco peregrinus*)[1](ST)[2]
Federal Threatened Species Known to Occur at Rocky Flats	
Birds:	Bald Eagle (*Haliaeetus leucocephalus*)[3] (ST)
Federal Proposed Species Known to Occur at Rocky Flats	
Mammals	Preble's Meadow Jumping Mouse (*Zapus hudsonius preblei*)[5,8](SC)
Federal Special-Concern Species Known to Occur at Rocky Flats	
Reptiles	Eastern Short Horned Lizard (*Phrynosoma douglassii brevirostra*)[4,5]
Birds	Northern Goshawk (*Accipiter gentilis*)[5,6]
	Baird's Sparrow (*Ammodramus bairdii*)[5]
	Western Burrowing Owl (*Athene cunicularia hypugea*)[4,5]
	Ferruginous Hawk (*Buteo regalis*)[4,5](SC)[7]
	Black Swift (*Cypseliodes niger*)[5,6]
	Loggerhead Shrike (*Lanius ludovicianus*)[4,5]
	White-faced Ibis (*Plegadis chihi*)[5]
Mammals	Small-footed Myotis (*Myotis subulatus = M. ciliolabrum*)[5,6]
Colorado Species of Special Concern Known to Occur at Rocky Flats	
Amphibians	Northern Leopard Frog (*Rana pipiens*)(SC)
Birds	Long-billed Curlew (*Numenius americanus*)[6](SC)
	Greater Sandhill Crane (*Grus canadensis tibida*)[6](ST)
	American White Pelican (*Pelecanus erythrorhynchos*)[4](SC)
Federal Endangered Species with Potential Habitat at Rocky Flats	
Birds	Whooping Crane (*Grus americana*)
	Least Tern (*Sterna antillarum*)
	Piping Plover (*Charadrius melodus*)
Mammals	Black-footed Ferret (*Mustela nigripes*)[9]
Federal Threatened Species with Potential Habitat at Rocky Flats	
Plants	Ute Ladies'-tresses (*Spiranthes diluvialis*)[10]
Federal Threatened Species with Potential Habitat at Rocky Flats (Cont.)	
Insects	Pawnee Montane Skipper (*Hesperia leonardus montana*)
Federal Candidate Species with Potential Habitat at Rocky Flats	
Plants	Colorado Butterfly Plant (*Gaura neomexicana* var. *coloradensis*)(C1)[11]
Birds	Mountain Plover (*Charadrius montanus*)(C1)
	Southwestern Willow Flycatcher (*Empidonax traillii extimus*)(C1)
Federal Special-Concern Species with Potential Habitat at Rocky Flats	
Plants	Bell's Twinpod (*Physaria bellii*)[5]
	Tulip Gentian (*Eustoma grandiflora*)[5]
	Adder's Mouth Orchid (*Malaxis brachypoda*)[5]
Insects	Regal Fritillary (*Speyeria idalia*)[5]
Fish	Plains Topminnow (*Fundulus sciadicus*)[5]
Birds	Western Snowy Plover (*Charadrius alexandrinus nivosus*)[5]
	Black Tern (*Chlidonias niger*)[5]
Mammals	Spotted Bat (*Euderma maculatum*)[5]
	Long-eared Myotis (*Myotis evotis*)[5]
	Fringed Bat (*Myotis thysanodes*)[5]
	Long-legged Myotis (*Myotis volans*)[5]
	Pale Townsend's Big-eared Bat (*Plecotus townsendii pallescens*)[5]
	Plains Spotted Skunk (*Spilogale putorius interrupta*)[5]
	Swift Fox (*Vulpes velox*)[9,5]

Colorado Species of Special Concern with Potential Habitat at Rocky Flats	
Fish	Common Shiner (*Notropis cornutus*)(SC)
	Stonecat (*Noturus flavus*)(SC)
Birds	Barrow's Goldeneye (*Bucephala islandica*)(SC)
	Plains Sharp-tailed Grouse (*Tympanuchus phasianellus jamesi*)(SE)[12]
Watch-Listed Species Known to Occur at Rocky Flats	
Birds	Black-crowned Night-heron (*Nycticorax nycticorax*)[13]
	Cooper's Hawk (*Accipiter cooperii*)[13]
	Sharp-shinned Hawk (*Accipiter striatus*)[13]
	Golden Eagle (*Aquila chrysaetos*)[13]
	Swainson's Hawk (*Buteo swainsoni*)[14]
	Northern Harrier (*Circus cyaneus*)[15]
	Merlin (*Falco columbarius*)[13]
	Prairie Falcon (*Falco mexicanus*)[13]
	Short-eared Owl (*Asio flammeus*)[15]
	Long-eared Owl (*Asio otus*)[13]
	Olive-sided Flycatcher (*Contopus borealis*)[15]
	Chestnut-sided Warbler (*Dendroica pensylvanica*)[15]
	Virginia's Warbler (*Vermivora virginiae*)[15]
	Baird's Sparrow (*Ammodramus bardii*)[15]
	Grasshopper Sparrow (*Ammodramus savannarum*)[15]
	Lark Bunting (*Calamospiza melanocorys*)[15]
	Chestnut-collared Longspur (*Calcarius ornatus*)[15]
	Field Sparrow (*Spizella pusilla*)[15]

NOTES:

1. The species *Falco peregrinus* is listed as endangered wherever found in the coterminous 48 states. Some subspecies are listed separately.
2. Colorado State threatened species (ST).
3. The USFWS has down-listed the Bald Eagle to threatened status.
4. This species is resident or regularly visits Rocky Flats.
5. In February 1996, the U. S. Fish and Wildlife Service (USFWS) revised the list of candidate species to include only proposed and C1 species. All former candidate species except C1 species are now classified unofficially as "at-risk" and are still considered special-concern species. The search-list includes these species because they may be upgraded to C-1 species at any time.
6. The species has been observed infrequently on Rocky Flats, in some cases the observation made was of an individual flying over the Site, not of an individual on the ground.
7. Colorado species of special concern (SC).
8. In March 1997 the USFWS published a proposal to list the Preble's meadow jumping mouse as an endangered species. The final listing decision is pending.
9. This species was previously collected near Rocky Flats.
10. These species have historically used areas in the vicinity, and suitable feeding or residential habitat exists at Rocky Flats.
11. Federal candidate species for listing as threatened or endangered (C1).
12. Colorado State endangered species.
13. Colorado Natural Heritage Program list of rare and imperiled species.
14. Species of special interest to th e Colorado Division of Wildlife due to recent winter range die-off of the species.
15. Birds listed by the USFWS as "Migratory Nongame Birds of Management Concern: the 1995 List" that occur at the Site.

Note: Candidate species lists are under constant revision. As data are reviewed by the USFWS, species are added to and removed from this list on a year-round basis. This list for Rocky Flats Environmental Technology Site is updated annually.

Sources:

1. Colorado Natural Heritage Program 1996 List of Rare and Imperiled Animals, Plants, and Natural Communities.
2. Federal Register, February 28, 1996, pp. 7596-7613.
3. Migratory Nongame Birds of Management Concern in the United States: the 1995 List.

Significant Species

Significant species monitored during 1996 included special-concern species, big game mammals, mid-sized mammals, carnivores, waterfowl, raptors, and herptiles (reptiles and amphibians). A list of the species included in these groups is provided in Appendix A, along with a description of the SSD data entry process. Discussions in the following sections concentrate on area and habitat use by the various significant species groups.

Special-Concern Species

Special-concern species are a particular class of wildlife and plants that are of special interest at the Site due to their protected status or rarity. These have been designated on the basis of their rare or imperiled status, as identified by the U.S. Fish and Wildlife Service (USFWS), the Colorado Division of Wildlife (CDOW), the Colorado Natural Heritage Program (CNHP), and others. Species placed in this category by the NRCPP are federally listed threatened and endangered species; species formerly listed by the USFWS as candidate species; Colorado threatened, endangered, or Colorado Species of Special Concern; species from the CNHP lists of rare and imperiled species; and species "watch-listed" by other regulatory or natural resource conservation groups. While the majority of these species that occur, or have potential to occur, at the Site are animal species, a few plant species are also included. It should be noted that these species are designated as special-concern because of their rarity. Observations of rare species are inherently sporadic and infrequent; consequently, many of these species may not be observed at the Site every year. Lack of observations of special-concern species at the Site in any given year is not considered cause for alarm, but no observations of a species for several years in a row would trigger a more intensive search, particularly if there had been no reported regional decline in the species.

Two threatened or endangered species use the Site seasonally. There are, however, 10 federal special-concern species documented, and an additional four Colorado Species of Special Concern. Table 3-1 presents the Site's 1996 search list for special-concern species

Threatened and Endangered Species

Threatened and endangered species that used the Site during 1996 included the bald eagle (*Haliaeetus leucocephalus*) and the American peregrine falcon (*Falco peregrinus*). While these two species are not permanent residents at the Site, they do forage seasonally within the boundaries of the Buffer Zone. They are considered of concern, and are monitored, because of their protected status under the ESA. Site activities must be planned such that no take (harassment or harm) of these species occurs during the time they are present within Site boundaries.

Federal Proposed Species

The Preble's meadow jumping mouse (*Zapus hudsonius preblei*), a special-concern species at the Site, was proposed for listing as an endangered species in the March 25, 1997 Federal Register.

Federal Special-Concern Species

Federal special-concern species observed during 1996 included the eastern short horned lizard (*Phrynosoma douglassii brevirostra*), the loggerhead shrike (*Lanius ludovicianus*), the northern goshawk (*Accipiter gentilis*), the ferruginous hawk (*Buteo regalis*), and the white-faced ibis (*Plegadis chihi*).

Colorado Species of Special Concern

Colorado Species of Special Concern using the Site during 1996 included northern leopard frog (*Rana pipiens*) and the American white pelican (*Pelecanus erythrorhynchos*).

Watch-Listed Species

Watch-listed species observed at the Site during 1996 included the short-eared owl (*Asio flammeus*), the long-eared owl (*Asio otus*), the Swainson's hawk (*Buteo swainsoni*), the merlin (*Falco columbarius*), the northern harrier (*Circus cyaneus*), the Cooper's hawk (*Accipiter cooperii*), the sharp-shinned hawk (*Accipiter striatus*), the prairie falcon (*Falco mexicanus*), the golden eagle (*Aquila chrysaetos*), the black-crowned night-heron (*Nycticorax nycticorax*), the field sparrow (*Spizella pusilla*), and the grasshopper sparrow (*Ammodramus savannarum*). The latter two species are not illustrated on Figure 3-1 because of the relatively larger numbers of passerine bird (songbird) observations at the Site (e.g., grasshopper sparrows, though declining in other areas, are quite common in grasslands at the Site).

General Discussion of Special-Concern Species

The species grouped together as special-concern species are from diverse taxonomic classifications, and therefore, are found in a variety of habitats. While the majority of special-concern species using the Site are raptors, other groups represented include herptiles, mammals, passerine birds, and water birds. Special-concern species using Rocky Flats are generally concentrated near the main watercourses, which is not unexpected of predominantly predatory species, nor of other species groups. Prey species are also more concentrated in these habitats. Table 3-2 presents a habitat use summary for all special-concern species (except grasshopper sparrows and field sparrows) observed during 1996.

Threatened and endangered species were rare at the Site. Bald eagles were observed mostly in the extended observation area (EA) outside the Site boundaries near the active Standley Lake nest. Because the majority of the observations were made in the vicinity of the nest, the habitat use observations were limited to riparian woodland. Bald eagles periodically make foraging flights over portions of the Site, and therefore may be observed over nearly any habitat (EG&G 1995a; RMRS 1996). Peregrine falcons have nested in the Flatirons, a few miles northwest of the Site, for several years (EG&G 1995b). A single American peregrine falcon was recorded at the Site during 1996. This individual was observed perched on a pole in xeric mixed grassland. Previous habitat use for the species at the Site has also included areas surrounding impoundments (DOE 1992; EG&G 1995a; RMRS 1996).

Federal special-concern species were observed periodically at the Site. Eastern short horned lizards were observed in xeric mixed grassland. This is apparently the preferred habitat for the species at the Site (DOE 1992; EG&G 1995a; RMRS 1996). Loggerhead shrikes were observed in a variety of habitats, but were seldom far from woody vegetation (woodland or shrubland). A northern goshawk and ferruginous hawks were recorded in riparian woodland, and white-faced ibis were found in association with water (mudflats or grassland adjacent to water).

The Preble's meadow jumping mouse, a species recently proposed for listing as endangered, was recorded in association with riparian shrubland (*Salix* dominated) and tall upland shrubland. This species is most strongly associated with the Great Plains riparian complex of the creek bottomlands, where water is readily available. Although the tall upland shrubland community is quite different from the riparian zone, the mouse is also present in portions of the tall upland shrubland. This is most likely because the tall upland shrubland is closely associated with active hillside seeps that provide the apparently requisite water source for the mouse. During 1996, two trapping study reports on this species were produced (K-H 1996a,b); therefore, no more detailed information is presented here.

Other Colorado Species of Special Concern also were observed at the Site. Northern leopard frogs were found in association with water (mudflats or grassland adjacent to water). Although American white pelicans were only observed in flight over grasslands at the Site during 1996, this species normally is associated with open-water habitat (EG&G 1995a; RMRS 1996).

A number of watch-listed species were observed at the Site. Black-crowned night-herons were found in riparian woodland on impoundment margins. Northern harriers were observed in a wide variety of habitats. Cooper's hawks were recorded in riparian woodland. Golden eagles, prairie falcons, and Swainson's hawks were most commonly found in association with either riparian woodland (roosting and nesting) or grasslands (foraging). A single observation of a merlin was made in reclaimed grassland in close association with riparian woodland. Short-eared and long-eared owls also showed an affinity for woody vegetation, with observations of long-eared owls in tall upland shrubland and riparian woodland, and short-eared owls in tall upland shrubland, xeric mixed grassland, and wetlands. Field sparrows were observed in association with wetlands and in xeric tallgrass habitat. Grasshopper sparrows were common to abundant in the xeric and mesic grasslands at the Site, and are also found in lower numbers in reclaimed grassland. The single observation of a sharp-shinned hawk was in mesic mixed grassland.

4.9.7 General Discussion - Species Diversity (BIODIVERSITY)

Since 1991, 187 species of birds (including 19 raptors), 3 big game species, 11 species of carnivores, 9 species of mid-sized mammals, 20 small mammal species, eight reptile species, and seven amphibian species have been recorded at the Site. Such species diversity is impressive for a site of such small size. The diversity and continued use of the Site by special-concern species verifies that habitat quality for these species has remained acceptable. Of particular interest is a species diversity comparison between the Site and Rocky Mountain National Park (RMNP). While the Site is only 2 percent the size of RMNP, and has only three life-zones, as compared to 10 in the park, the number of mammal and herptile species is comparable (43 versus 48, and 7 versus 5, respectively). The numbers of bird species also correlates well, with 187 species recorded at the Site versus 268 recorded in RMNP. Thus, the Site exhibits a species richness that is 68 percent of that in RMNP at only 2 percent of the acreage. It should be noted that 36 of the bird species at the Site and 94 of those in RMNP are listed as "rare," so the Site supports 151 "normal" species, compared to 174 "normal" species in RMNP (or 87 percent of the species richness). Table 3-13 presents a comparison summary of Site fauna to nearby Jefferson County and Boulder Open Space lands, and RMNP. This comparison demonstrates the excellent overall species diversity at the Site, indicating that Site habitats are of high quality, although some of the habitat has been degraded and continues to be threatened by the invasion of noxious weeds.

The biogeography of the Site results in a patchwork of diverse communities that provide habitat for a rich array of species. Eleven native plant community types are recognized at the Site (Figure 4.9-1 and Table 4.9-1). The diverse life history needs of ecological generalists such as coyotes and black-billed magpies and ecological specialists such as Preble's meadow jumping mice and long-eared owls are met at this site. Other species may use the Site to meet some portion of their ecological requirements. Raptors typically have large home ranges that include different areas for nesting, hunting, roosting, and perching. The Site is used by red-tailed hawks, American kestrels, great horned owls, and others for various portions of their life history needs.

Species richness is one measure of biodiversity. To be most meaningful, however, richness may be combined with an assessment of species composition. For example, an early successional community may have a high diversity of non-native weedy species. Therefore, this analysis focuses on both the number of species present (richness) and the percent composition of native plant species ("nativeness"). To date, 512 species of vascular plants and 212 species of vertebrates have been documented at the Site (EG&G 1994g). The vertebrate species include 33 mammals, 156 birds, 8 reptiles, 6 amphibians, and 9 fish. In studies for the Ecological Monitoring Program at the Site in 1993 and 1994, a total of 316 plant species were encountered within 60 sampling areas; of these species, a high proportion (nearly three-fourths) were native.

On a regional scale, the Site can be viewed in relation to other land parcels in the Front Range Urban Corridor that are known for their diverse and native biotic communities. Rocky Mountain Arsenal is a 27-square-mile site with a history of chemical production. The industrial area at the Arsenal, as is the case for the Site, is located in the center of a large buffer zone that supports abundant wildlife. After cleanup at Rocky Mountain Arsenal is completed, it will become a National Wildlife Refuge. Buckley Air National Guard Base and the Plains Conservation Center, although both smaller than the Site, are also relatively large tracts of land. The Plains Conservation Center was established specifically for the purpose of educating people about native prairie grasslands. All of these parcels are sanctuaries that contain various types of well-developed native grassland.

Existing data on plant species richness, percent native plant cover, and relative abundance and richness of small mammals and grassland songbirds were used to compare biodiversity at the Site with the Rocky Mountain Arsenal, Buckley Air National Guard Base, and the Plains Conservation Center. Differences among the sites (e.g., areal extent and sample size) must be recognized and considered in such a broad-scale comparison. The purpose of this comparison is not to evaluate specific numerical values but to show that the Site, on the whole, is comparable to the other three sites. Data were collected for the purpose of documenting biotic resources at these other sites (Shell 1989a and 1989b) . Values for Rocky Flats were extracted from environmental evaluation data collected from OU2 (903 Pad) study sites and Rock Creek and Smart Ditch reference areas, which are typical of conditions at the Site. Data from the 903 Pad (the most disturbed part of OU2) were not included in the analysis because no comparable areas occur at the other sites.

Table 4.9-5 provides a comparison of plant communities at each of the four grassland sites noted above. The comparison of plant species richness and percent of natives shows that, although the Rocky Mountain Arsenal had the highest total species richness (133 species versus 116, 120, and 127 species), it is also the largest of the four sites. Percent native cover was highest at Rocky Flats and Buckley Air National Guard Base (81.5% and 81.7%, respectively). The Rocky Mountain Arsenal and the Plains Conservation Center had lower percent native cover values of 72.0% and 65.3%, respectively.

Table 4.9-5. Comparison of Plant Communities at Four Grassland Sites on the Colorado Front Range

Description	Rocky Flats Environmental Technology Site	Rocky Mountain Arsenal	Buckley Air National Guard Base	Plains Conservation Center
Total Area	10 mi^2	26 mi^2	5 mi^2	3 mi^2
Season and Year	June-Sept. 1991	June-Sept. 1986	June-Sept. 1986	June-Sept. 1986
Number of Sites Sampled	100	83	57	51
Habitat Type Studied	Xeric mixed grassland; Mesic mixed grassland	Native perennial grassland	Mixed grass prairie	Mixed grass prairie
Species Richness	116	133	120	127
Percent Native Cover	81.5	72.0	81.7	65.3

Note: Site data from OU2 (903 Pad) environmental evaluation collected by EG&G; other data from Shell (1989b).

A comparison of small mammal and bird relative abundance and species richness is shown in Table 4.9-6. No data were available for small mammals from the Plains Conservation Center (Shell 1989b). Small mammal relative abundances, which are known to fluctuate over time and locality, were surprisingly similar for Rocky Flats, Rocky Mountain Arsenal, and Buckley Air National Guard Base (11.1, 10.7, and 9.4 individuals captured per 100 trap-nights, respectively). Although one more species was captured at the Site (8 versus 7 and 7 species), this can probably be attributed to the much larger number of sampling areas (19 versus 5 and 3 sampling areas).

Table 4.9-6. Comparison of Species at Four Sites on the Front Range

Name of Site	Mammals	Birds	Reptiles	Amphibians	Life Zones	Acreage
Rocky Flats	43 species	187 species	8 species	7 species	3	6,262
	recorded	recorded	recorded	recorded		
Rocky Mountain National Park (1)	48 species	268 species	1 species	5 species	10	266,880
	recorded	recorded	recorded	recorded		
City of Boulder Open Space (2,3)	81 species	252 species	21 species	6 species	6	26,000
	recorded & expected	recorded & expected	recorded & expected	recorded & expected		
Jefferson County Open Space (4)	18 species	50 species	N/A (5)	N/A	5	1,721
(Deer Creek Park)	recorded	recorded				

NOTES:

1) Rocky Flats Environmental Technology Site is approximately 2% the size of Rocky Mountain National Park.
2) City of Boulder Open Space species lists include both species known to occur and species expected to occur due to the presence of appropriate habitat.
3) Rocky Flats Environmental Technology Site is approximately 24% the size of all combined City of Boulder Open Space holdings.
4) Rocky Flats Environmental Technology Site is approximately 364% the size of Jefferson County Open Space's Deer Creek Park.
5) N/A = No available data

SOURCES:

Listing of vertebrate animal and vascular plant species, Rocky Mountain National Park (RMNP 1990)
Unpublished species lists of birds, mammals, reptiles and amphibians, City of Boulder Open Space (CBOS 1997)
Mammals of Deer Creek Park and Deer Creek Park (DCP) Bird Species List (JCOS 1996a, b)

Relative abundance of birds was highest at the Plains Conservation Center (5.0 nesting pairs per sampling site) and lowest at Rocky Mountain Arsenal (2.0 nesting pairs per sampling site). Abundances for Rocky Flats and Buckley Air National Guard Base were intermediate (3.5 and 4.1 nesting pairs per sampling site, respectively). Nesting species richness was very similar across the four sites (3, 3, 4, and 4 species, respectively), as was species composition.

As described above, an important component of biodiversity is the extent to which an area contains species that are representative of native community types. Another measure of this quality is the occurrence of species of special concern (Section 4.9.6, "Species of Special Concern," and Table 4.9-4). The presence of these species indicates the presence of native habitats that support them.

Nine protected species have been observed at the Site. Forktip three-awn is known from only four localities in Colorado, including the Site. Habitats suitable for the Ute ladies-tresses and Colorado butterfly plant also occur on-site, as does a seemingly viable population of Preble's meadow jumping mice. No Preble's meadow jumping mouse populations are known from other localities; only individual captures from two locations in City of Boulder open space have been reported in recent years. All of these species have narrow ecological requirements, and their presence (or that of suitable habitat) reflects the preservation of native communities in much of the Buffer Zone.

In 1993, the Colorado Natural Heritage Program assessed the ecological values of the Rock Creek drainage at the Site. This area apparently was selected for assessment because of its isolation from the Industrial Area and the lack of related disturbance and contamination. Based on this assessment, the Rock Creek drainage was determined to contain substantial natural heritage resources (i.e., species or communities determined by the Colorado Natural Heritage Program to be rare, threatened or endangered, or of high significance) and was denoted as a Natural Heritage Conservation Site.

4.9.8 Baseline Risks to Ecological Resources

For case comparisons, a baseline condition describing the current risk to Site ecological resources must be established. Physical and chemical impacts to ecological resources at the Site have occurred as a result of historical and ongoing human activities. Physical disturbance caused by agricultural practices, construction, waste disposal, remedial activities, and surface water management has affected plant community structure and composition. Release of environmental contaminants during facility operations (including manufacturing and waste disposal) as well as accidental releases of contaminants into the environment are potential sources of chemical stress to plants and wildlife. These baseline impacts on ecological resources at the Site are discussed below.

Physical Stress

Stress from physical disturbance may affect organisms directly through injury or mortality or indirectly through loss or degradation of habitat. Physical impacts associated with past and continuing activities were identified from vegetation maps, aerial photographs, and historical records. Effects were evaluated by quantifying the area of each plant community (wildlife habitat) affected.

As discussed in Section 4.9.1, "Vegetation," the reclaimed and disturbed plant communities at the Site exist as a direct consequence of physical impacts to native plant communities. These habitat types account for 12% of the total area of the Site. Reclaimed and disturbed habitats are structurally simple, support relatively few plant species, contain populations of exotic weeds, and are often near to areas of ongoing human activity. Therefore, these areas are also generally lower-quality wildlife habitat. Together with developed areas (buildings, roads, parking lots), these areas represent 1,403 acres (22% of the Site) that probably supported native grasslands prior to the physical impacts of human activities.

All open-water pond habitat at the Site is also the result of physical impacts from human activity. The ponds were created by construction of dams for agricultural purposes (e.g., Lindsey Pond) or for control of surface water runoff (e.g., ponds in the Woman and Walnut Creek drainages). Without the dams, these areas would probably be riparian corridors interspersed with small, seasonally saturated marsh areas.

Water levels of detention ponds in the Walnut Creek drainage (A- and B-Ponds) and Woman Creek drainage (C-Ponds) are managed by batch discharge (see Section 4.4.4, "Surface Water Quality"). This results in widely and rapidly fluctuating water levels throughout the system, especially in the three terminal ponds (A-4, B-5, and C-2) and downstream reaches. Resultant adverse impacts on aquatic pond biota include physical stress, periodic loss of individuals or entire communities, and extremes in water physiochemical characteristics such as dissolved oxygen, temperature, pH, and turbidity. These impacts greatly limit the ability of the affected areas to support natural, diverse, and self-sustaining aquatic and riparian vegetation communities.

Chemical Stress

Environmental contaminants represent varying levels of potential risk to individuals or populations of ecological receptors (organisms and habitats). However, chemical stress, if any, is often not visually obvious because most areas potentially affected by contaminants have also been physically disturbed.

Chemicals that pose a risk to ecological resources were identified through an EPA-approved data screening process conducted for Site ecological risk assessments (DOE 1995b). Chemicals identified by this methodology are referred to as "ecological chemicals of concern." The screening process for ecological chemicals of concern was based on 18 source areas. Each source area includes individual hazardous substance sites with similar contamination histories and adjacent areas that may or may not be contaminated. This approach was used so that risks from chemical exposure could be calculated for areas of more ecologically relevant size than single individual hazardous substance sites, some of which are very small. The screen was based on conservative assumptions that minimize the likelihood of underestimating exposure and risk to ecological receptors.

Exposure and risk were initially calculated for a large number of potential chemicals of concern identified in abiotic media (soil, water, sediments) at the Site. For each potential chemical of concern, exposures to ecological receptors (plants and animals) were estimated separately for contact with each abiotic and biotic (small mammal and vegetation tissue) environmental medium. Risk for each receptor was based on the cumulative exposure from all media. This process was conducted for key taxa representing ecological resources at the Site. The results of the screen were used to identify chemicals that represented potential risk to ecological resources and the media that contributed most to that risk.

Three of the ecological resources discussed in previous sections were identified as potentially at risk from chemical exposure under baseline conditions: vegetation (upland and wetland), wildlife, and aquatic fauna. These risks are briefly discussed below.

VEGETATION. Several source areas were identified with metal and nitrate concentrations that could be toxic to plants. The source areas were located in upland soils supporting native grassland habitats. However, impacts on plant community composition in these source areas are not necessarily attributable to chemical toxicity. Metals that exceed risk criteria for wetland vegetation were also identified in stream and pond sediments in several source areas. Wetlands and native grasslands are both considered sensitive habitats at the Site, as defined in Section 4.9.3, "Sensitive Habitats."

WILDLIFE. Chemical impacts to wildlife were evaluated for both terrestrial- and aquatic-based birds and mammals and included potential exposure through ingestion of food, water, and soil/sediment; through inhalation; and through dermal contact with contaminants. The screen for ecological chemicals of concern indicated that risks of toxic exposure were negligible for wide-ranging species such as red-tailed hawks, coyotes, and deer. However, species with more restricted home ranges such as the Preble's meadow jumping mouse, American kestrel, great blue heron, and mallard may have more frequent contact with chemicals in contaminated areas and may be more likely to experience toxic exposures.

The screen indicated that some metals, organic compounds, and radionuclides may be present in some source areas at potentially toxic concentrations to some wildlife receptors. Most of these chemicals are metals in soils and prey items and pose little risk to wildlife. However, the risk to small mammals from exposure to toluene in burrow air in the OU2 903 Pad and East Trenches source areas is considerable. The risk for small mammals from uranium in surface soils in the Original Landfill in OU5 is also potentially high. Great blue herons are at risk from exposure to organic compounds in aquatic prey in the South Interceptor Ditch in the OU2 903 Pad and OU6 A-Pond source areas as well as mercury in aquatic prey in the streams and ditch in the OU5 Original Landfill source area (DOE 1995b).

The Preble's meadow jumping mouse is a species of special concern at the Site. The screen for ecological chemicals of concern showed that the Preble's meadow jumping mouse is at potential risk from exposure to metals in vegetation at the North Spray Field source area in OU6 (Walnut Creek Drainage) and the Solar Evaporation Ponds source area in OU7 (Present Landfill). These risks are considered to be minor (DOE 1995b).

AQUATIC FAUNA. The screen identified organic compounds and metals in stream and pond sediments and surface water that exceed risk criteria for aquatic fauna in several source areas. Evaluation of aquatic communities indicates that these ecological chemicals of concern may have only minor impacts on aquatic biota.

international history for their contribution to the Cold War Era. These cultural resource elements are listed in Table 4.10-1, and the location of these facilities is depicted in Figure 4.10-1.

Table 4.10-1. Cold War Era Resources of Rocky Flats Historic District

Primary Contributors			
Building 100—Guard Post, Inner West Gate	Building 372A—Guard Post for Building 371	Building 762A—Badge Check	Building 888—Guard Post, Building 865
Building 111—Original Clock Room/Administration	Building 375—Observation Tower, Protected Area	Building 764—PIDAS Security Station	Building 900—Guard Post, Inner East Gate
Building 112—Original Cafeteria	Building 440—Truck Modifications	Building 771—Original Plutonium Production	Building 901—Guard Tower, Protected Area
Building 113—Guard Post, Central Avenue West	Building 442—Original Laundry and Filter Test Lab	Building 773—Original Guard Post for Building 771	Building 920—Guard Post, East Gate
Building 114—Bus Stop	Building 444—Original Depleted Uranium Production	Building 776—Plutonium Casting	Building 991—Original Packing and Shipping
Building 120—Guard Post, West Gate	Building 446—Original Guard Post for Building 444	Building 777—Plutonium Assembly	Building 992—Original Guard Post for Building 991
Building 121—Original Plant Safety	Building 460—Stainless Steel Fabrication	Building 778—Laundry for Buildings 776/777	Building 996—Original Storage Vault
Building 122—Original Medical Building	Building 461—Guard Post for Building 460	Building 792—Guard Post, Protected Area	Building 997—Original Storage Vault
Building 123—Original Health Physics Laboratory	Building 557—Guard Post	Building 792A—Badging Station for Building 771	Building 998—Original Storage Vault
Building 133—Guard Post, West Parking Lot	Building 701—Experimental Laboratory	Building 864—Original Guard Post for Building 881	Building 999—Storage Vault
Building 331—Original Fire Station and Garage	Building 707—Plutonium Production	Building 881—Original Enriched Uranium Production	
Building 371—Plutonium Recovery	Building 761—Guard Tower, Protected Area	Building 883—Rolling and Fabricating	
Building 372—Guard Post, Protected Area	Building 762—Guard Post, Protected Area	Building 886—Criticality Laboratory	
Secondary Contributors			
Building 124—Original Water Treatment Plant	Building 333—Original Paint/Blast Shop	Building 443—Original Heating Plant	Building 779—Plutonium Laboratory
Building 125—Standards Laboratory	Building 334—Original Maintenance Shop	Building 551—Original Warehouse	Building 865—Metal R&D Laboratory
Building 126—Calibration Laboratory	Building 374—Waste Treatment for Building 371	Building 559—Analytical Laboratory for Plutonium	Building 995—Original Waste Water Treatment
Building 215A—Original Water Tower	Building 441—Original Admin/Production Support	Building 774—Original Waste Treatment for Building 771	

The normal age of cultural resources qualifying for eligibility for the National Register is fifty years or older. All of the facilities at the Site are less than 50 years old. The Department of Interior *Guidelines for Evaluating and Nominating Properties that have Achieved Significance Within the Last Fifty Years* indicates that properties less than 50 years old must have "exceptional importance," either individually or as a district, to be eligible for the National Register of Historic Places (NPS 1990a).

The State Historic Preservation Officer has determined that the 64 facilities listed in Table 4.10-1 are eligible for the National Register of Historic Places as an historic district. According to Department of Interior guidelines, an eligible historic district possesses a significant concentration, linkage, or continuity of sites, buildings, structures, or objects historically or aesthetically united by plan or physical development (NPS 1991). The Cold War Era facilities listed were either primary contributors to the production of weapons or secondary contributors to the central mission of the plant. Both categories, however, have equal importance in the context of the historic district

4.10 Cultural Resources and Paleontology

Cultural resources are material remains and artifacts from human activities. Historic cultural resources generally date from 50 years before the present to the earliest written records for an area. Cultural resources predating the earliest written records are considered prehistoric. The Site includes important historic properties that have been identified through systematic surveys conducted by the Department of Energy.

Paleontological Resources

The Site contains Cretaceous bedrock of claystone, siltstone, and sandstone overlain in most areas by Holocene alluvial deposits. These deposits are not fossil-bearing at the Site. Paleontological resources were not recorded during either of two site assessments conducted for DOE and are not believed to be present in the exposed geologic strata at the Site.

Prehistoric Resources

The Site was occupied since at least the Middle Ceramic Period (1000 to 1800 AD) by American Indian groups. Few material remains from this period have been found at the Site. DOE has conducted two systematic archaeological surveys in the Buffer Zone. No prehistoric resource surveys have been conducted in the Industrial Area which has been highly disturbed through excavation and construction. Five prehistoric cultural resources (two sites and three isolated finds) consisting mainly of rock cairns have been found in the Buffer Zone. Other artifacts of possible prehistoric origin have not been dated with any certainty. None of the identified prehistoric resources is considered eligible for the National Register of Historic Places. The State Historic Preservation Officer does not recommend any further investigation on prehistoric resources at the Site.

Traditional Cultural Properties

Traditional cultural properties are properties or places that are eligible for inclusion in the National Register of Historic Places because of their association with cultural practices and beliefs that are either rooted in the history of a community or important to maintaining the continuity of that community's traditional beliefs and practices. Traditional cultural properties may be either prehistoric or historic resources. Traditional cultural properties eligible for the National Register of Historic Places have not been identified at the Site.

Historic Resources

The historic occupation of the Site began after 1850, with early Anglo-American settlers applying for land ownership and patents beginning in 1867 (D&M 1991). During two separate DOE cultural resource surveys, 38 historic sites and 15 isolated historic finds of greater than 50 years in age were located in the Buffer Zone. An evaluation for eligibility for the National Register of Historic Places determined that none of the 53 historic resources in the Buffer Zone are significant to the historical development of the region or associated with important persons or events, and they are therefore ineligible for the National Register. No historic resources over 50 years old are reported inside the Industrial Area.

A recent historical phase began at the Site in 1951 with the purchase of land by DOE for a nuclear weapons facility. From that date until 1989 when production operations ceased, the plant was one of only 13 sites used for nuclear weapons production in the United States during the Cold War Era. DOE conducted a survey of cultural resources in the Industrial Area in 1995 and has evaluated the Cold War Era resources using Department of Interior guidelines. Based on this evaluation, 64 facilities at the Site were determined to be highly important to regional, national, and because they functioned together to provide the characteristic activity of nuclear weapons production during the Cold War.

In consultation with the State Historic Preservation Officer and the Advisory Council on Historic Preservation, DOE is developing a Programmatic Agreement for the treatment and preservation of the significant information about the historic district (DOE 1997). The National Park Service has provided guidelines to DOE concerning how to document the facilities and the history of the plant before cleanup and closure activities alter their historical significance. This information will be submitted to the National Archives for preservation. An evaluation of the effects of any proposed actions involving the historic properties, such as internal structural modification or demolition, will be required to develop mitigation measures to reduce any adverse effects to non-adverse levels until the documentation for the affected property is completed.

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4.11 Noise

Major noise sources at the Site include various industrial activities and construction of a new sanitary landfill. Examples of noise sources include cooling towers, transformers, engines, pumps, boilers, steam vents, paging systems, construction and materials-handling equipment, and vehicles. The primary noise source to nearby residential areas is vehicular traffic (DOE 1992d). Prohibition of nuisance noise is the only noise standard applied to the Site by Colorado or local governments. Jefferson County has established noise abatement regulations to protect the public from potential harmful effects of noise pollution. These regulations designate acceptable levels of noise pollution in ambient air. The Jefferson County Environmental Health Department has jurisdiction to regulate noise levels as defined by Colorado Revised Statute, 1989, Article 12, "Noise Abatement." Maximum permissible daytime and nighttime noise levels for established zones are listed in Table 4.11-1.

Table 4.11-1. Maximum Permissible Noise Levels (Decibels)

Zone	7:00 am to 7:00 pm	7:00 pm to 7:00 am
Residential	55	50
Commercial	60	55
Light Industrial	70	65
Industrial	80	75

The Site is classified as an industrial facility and is required to keep noise levels below the daytime and nighttime standards of 80 decibels (dB) and 75 dB, respectively, at a distance of 25 feet or more from the property line as measured on the A-Scale (dBA).

4.11.1 Public Noise Levels

A noise measurement survey was conducted in September 1995 to determine background noise levels near the Site. Six noise-sensitive receptor sites were selected on the basis of their existing uses and proximity to the Site. The noise measurement sites selected and the noise levels recorded during the survey are listed in Table 4.11-2.

Table 4.11-2. Background Noise Levels at Selected Receptor Sites

Site	Location	Noise Level
Site 1	Equinox Equestrian Center	46 dBA
Site 2	Residential property at Alkire Street	41 dBA
Site 3	Open space area along Indiana Street	57 dBA
Site 4	New residential development along McCaslin Boulevard	40 dBA
Site 5	Open space area along Colorado State Highway 128	39 dBA
Site 6	Residential area along Colorado State Highway 93	61 dBA

Sites 1, 2, 4, and 6 are zoned for residential land use, and sites 3 and 5 are zoned for open space/agricultural use. At each of the sites, 20-minute sampling measurements were recorded between 9 a.m. and 5 p.m.

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The primary source of noise to nearby residential areas is traffic movements along local streets and state routes. The noise levels at each of the noise-sensitive receptor sites varied depending on proximity to traffic. Site 6 is the closest receptor site to a state highway and, as a result, had the highest measured background noise level. Noise levels from industrial activities within the Site boundary were not distinguishable from background traffic noise levels. It should be noted that most of the traffic volume on these transportation corridors is not attributable to Site activities. Neither the Broomfield Police Department nor the Jefferson County Environmental Health Department has logged any complaints of noise in the area surrounding the Site (Meskimen 1994, Sandson 1994).

4.11.2 Worker Noise Levels

In accordance with Site procedures, on-site industrial hygiene practices ensure hearing protection for workers. The hearing conservation program is a three-stage program that involves identification, training, and medical screening.

- **Identification:** High noise areas (noise levels of 85 dBA or greater) are identified by the Site occupational health and safety staff. The medical staff then identifies workers who may be exposed to areas known to have high noise levels under normal operations.
- **Training:** Workers who are at risk of exposure to high noise levels must attend training that addresses the importance of hearing conservation and hearing protection. These workers are required to wear appropriate hearing protection devices when working in areas known to have high noise levels.
- **Medical Screening:** Workers who have been exposed to high noise levels must have annual audiograms. If a hearing loss is identified by the audiogram, workers are referred to a physician and treated on a case-by-case basis.

Noise limits for workers at the Site are set in accordance with OSHA standards (29 CFR 1910.95), which state that Site workers must wear hearing protection devices when exposed to noise levels above 85 dBA for the 8-hour time-weighted

4.12 Socioeconomics

This section provides descriptions of the Site's influence on employment, the local economy, population and housing, and quality of life under base case conditions. A summary of historic and recent socioeconomic conditions for the State of Colorado and the Denver Metropolitan Area is also provided as background information.

4.12.1 Historic Conditions

In 1995, approximately 3.8 million people resided in the State of Colorado. There were approximately 2 million jobs state-wide. The eight-county Denver Metropolitan Area, including the principal counties of Adams, Arapahoe, Boulder, Denver, Douglas, and Jefferson, had a population of approximately 2 million people (54% of the state) and 1.2 million jobs (58% of the state). Metropolitan-area economic activity has a strong influence on the state as a whole.

As shown in Table 4.12-1, the population in Colorado increased an average of 1.6% per year between 1980 and 1995 (USBC 1994, CSDO 1995, DRCOG 1995a, Rand McNalley 1997). About one-half of the population increase was attributable to in-migration and the other half to natural increase (resident births, less deaths). In future years, net migration is expected to taper off as Colorado rates align more closely to national trends of slower growth.

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Table 4.12-1. Historic Population for Colorado and the Denver Metropolitan Area

Geographic Area	1980	1990	1995	Average Percent Increase/Year 1980-1995	Average Percent Increase/Year 1990-1995
Colorado	2,889,735	3,294,473	3,788,800	1.6	2.6
Denver Metropolitan Area	1,612,700	1,848,319	2,067,175	1.5	2.1

Within the Denver Metropolitan Area, population increased an average of 1.5% per year between 1980 and 1995 (comprising 50% of the state's increase). Employment increased at an average of 2.3% per year during this time period (comprising 50% of the state's increase).

As shown in Table 4.12-2, employment in Colorado increased at an average of 2.6% per year during from 1980 to 1995 (CDLE 1996b). Due to its reliance on tourism, mining, high technology, light manufacturing, and agriculture, Colorado growth has often diverged from national trends. Historical growth has been attributable primarily to increases in tourism (which is measured indirectly in the subsectors of retail trade and services), and residential and major public project construction. Recent federal defense budget cuts have reduced military employment and spending and some manufacturing activity. Mining and agricultural employment have been a small and unstable portion of total employment for many decades.

Table 4.12-2. Historic Average Employment by Place of Work

Geographic Area	1980	1990	1995	Average Percent Increase/Year 1980-1995	Average Percent Increase/Year 1990-1995
Colorado	1,232,133	1,503,621	2,044,700	2.6	5.3
Denver Metropolitan Area	785,491	946,076	1,189,100	2.3	4.1

Note: Employment excludes the self-employed, sole proprietors, railroad workers, and agricultural workers.

Since 1980, Denver Metropolitan Area employment has consistently increased in the wholesale, retail, services, financial, insurance, and real estate sectors. Manufacturing peaked in 1984 and has fluctuated since that time. Mining has continued to decline since its 1982 peak. Construction has trended upward as a result of large public-sector projects and residential construction fueled by substantial in-migration. Fluctuations in metropolitan area employment have also been due to oil and gas pricing (and related corporate decisions), international competition in the production of computers, construction and lending activity, and mortgage rates.

Between 1990 and 1995, the average annual rates of population and employment growth in the state and Denver Metropolitan Area exceeded projections as a result of one-time projects such as construction of Denver International Airport and Coors Field, substantial migration from California, and a favorable economic position relative to other portions of the United States.

Unemployment rates are an indirect measure of job opportunities for members of the labor force looking for work or considering a change in jobs. Unemployment rates are an important measure in this analysis because Site workers who might lose their jobs in future years may be seeking other job opportunities in the local economy.

As shown in Table 4.12-3, unemployment rates in Colorado have consistently remained below the national rate (CDLE 1996b). This trend occurs primarily because Colorado does not have high proportions of jobs in industries that are experiencing a general decline (e.g., low-technology manufacturing). Unemployment rates in the Denver Metropolitan Area consistently remain below the state average because of fewer seasonal, agricultural-based jobs and the general diversity of job opportunities in growing sectors.

Table 4.12-3. Historical Average Annual Rates of Unemployment

Geographic Area	1980	1990	1996
United States	6.5%	5.5%	5.3%
Colorado	5.9%	4.9%	4.1%
Denver Metropolitan Area	5.5%	4.5%	3.7%

Data for 1996 illustrate these trends. Unemployment in the United States averaged 5.3%, Colorado unemployment averaged 4.1%, and Denver Metropolitan Area unemployment averaged 3.7%.

The economic base of Colorado is structurally diverse. This diversification brings greater economic stability, enabling the state to absorb employment shocks more effectively than areas with more specialized economies.

Measured in terms of sales activity, the largest basic sectors in Colorado are manufacturing and tourism. Manufacturing includes primarily nonelectrical machinery, food products, printing and publishing, and instruments. Tourism is a multi-billion dollar business that is strongly influenced by the national economy and the strength of the dollar internationally. Individuals employed in tourism work for businesses in several industrial sectors, including retail trade, services, construction, transportation, and communications.

Measured in terms of employment, the services sector, which represents 28% of jobs in Colorado, and the retail trade sector, which represents 19% of jobs in Colorado, are the two largest sectors.

The economic base of the Denver Metropolitan Area is also diverse. As the largest metropolitan area in the Rocky Mountain states (Colorado, Montana, New Mexico, Utah, and Wyoming), Denver functions as the regional trade and services center in agriculture, finance, health services, and oil and gas. It is a regional distribution center because it contains the intersection of the main lines of two major railroads, the Burlington Northern and Union Pacific, and two interstate highways, I-25 and I-70. Each year, Denver attracts millions of visitors and convention delegates. During the last several decades, the metropolitan area has functioned as a magnet for high-technology computer and bio-technology production, cable television, and financial services management.

The diversity of the metropolitan area economy is illustrated by the variety of sectors represented by the top 15 private-sector employers in December 1996. As shown in Table 4.12-4, the Site (as represented by its Site contractor) ranked as the fourteenth-largest private-sector employer in the area (DBJ 1996).

Table 4.12-4. Largest Private-Sector Employers (Denver Metropolitan Area)

Business	Type	Location	Employment
U.S. West	Telecommunications	Arapahoe County and dispersed	17,246
King Soopers	Grocery	Denver County and dispersed	11,048
Columbia Colorado Division	Health Care	Jefferson County	9,898
AT&T	Communications	Denver County and dispersed	7,984
Lockheed Martin	Aerospace	Denver County	7,924
United Airlines	Commercial Air Carrier	Denver County	7,759
Coors Brewing Company	Brewer	Jefferson County	5,000
Centura Health Systems	Health Care	Denver County	4,258
Telecommuniciation, Inc.	Telecommunications	Arapahoe County and dispersed	4,134
Ball Corporation	Packaging & Aerospace	Jefferson County	3,623
Staff Administrators, Inc.	Professional Employer Services	Denver County	3,509
Public Service Company	Public Utility	Denver County and dispersed	3,487
Safeway	Grocery	Arapahoe County and dispersed	3,410
Kaiser-Hill Co., LLC RF	Environmental Restoration / Waste Management	Jefferson County	3,400
Storage Technology	Computer Production	Boulder County	3,200

4.12.2 Employment

Three Site-related types of employment are:

- *Direct Site employment*, which includes people employed by DOE, the Site contractor (Kaiser-Hill Company and first tier team of subcontractors).
- *Other direct employment*, which includes other subcontractors and vendors hired by DOE and the Site contractor.
- *Indirect employment*, which includes employees hired as a result of spending by Site employees and vendors.

These three types of employment collectively constitute total baseline employment. Total baseline employment for the Site in 1994 (including direct, other direct and indirect employees) was estimated at 16,533. As shown in Table 4.12-5, direct Site employment in 1996 totaled 6,977 workers.

Table 4.12-5. Estimated Direct Site Employment in Colorado – Baseline Conditions

Type	Denver Metropolitan Area	Other Colorado	Total
Direct Site (DOE, Site Contractor & Tier 1 Subs)	3,643	230	3,873
Estimated Other Direct (Protective Force & other Subcontractors)	2,918	186	3,104
Total Direct Employment[1]	**6,561**	**416**	**6,977**

[1]Does not include workers who reside outside Colorado.

As shown in the above table, estimated direct employment by subcontractors under baseline conditions was estimated at 3,104 workers. Because many subcontractors are not located at the Site full-time, for purposes of this analysis, it was assumed that 2,638 workers, or approximately 85% of total other direct Site workers, were located on-site at any given time. Indirect employees and vendors are assumed to work at the location of their employer, not at the Site.

As shown in Table 4.12-6, direct Site employment under baseline conditions represented 0.36% of total Colorado employment, 0.56% of Denver Metropolitan Area employment (CDLE 1996c).

Table 4.12-6. Direct Site Employment by Area – Baseline Conditions

Employees Residing In	Direct Site Employment	County, Metro, and State 1996 Employment[1]	Site Employment as Percentage of Total
Total Metro Area	6,561	1,159,500	0.56
Other Colorado	416	744,600	0.06
Total Colorado	**6,777**	**1,904,100**	**0.36**

[1]Excludes sole proprietors (individuals who work for themselves, are not covered by unemployment compensation and are generally excluded from state employment estimates).

As shown in Table 4.12-7, the total payroll for direct Site employment in 1994 was approximately $277 million ($262 million for the Denver Metropolitan Area). Because the average salary of Site workers is higher than the average salary of non-Site employees in the metropolitan area, the proportion of Site payroll to total metropolitan area payroll is higher than the proportion of Site jobs to total metropolitan area jobs. Direct Site payroll was 2.6% of total payroll in Boulder County, 1.6% of total payroll in Jefferson County, and 1.5% of total payroll in Adams County. In the remainder of the counties, direct Site payroll represented less than 0.5% of the county total (CDLE 1995a).

Table 4.12-7. 1994 Direct Site Payroll by County–Baseline Conditions

Employees Residing In	Direct Site Employment	County, Metro, and State 1994 Employment[1]	Site Employment as Percentage of Total
Adams County	$44,071,649	$2,896,953,214	1.5
Arapahoe County	$17,241,795	$6,237,890,853	0.3
Boulder County	$97,847,093	$3,812,600,233	2.6
Denver County	$21,882,569	$12,279,501,275	0.2
Douglas County	$1,656,811	$500,050,693	0.3
Jefferson County	$79,361,959	$5,049,936,067	1.6
Total Metro Area	**$262,061,876**	**$30,776,932,335**	**0.9**
Other Colorado	$14,821,633	$14,702,440,916	0.1
Total Colorado	**$276,883,509**	**$45,479,373,251**	**0.6**

[1]Excludes sole proprietors (individuals who work for themselves, are not covered by unemployment compensation, and are generally excluded from state employment estimates).

In Table 4.12-8, average 1996 baseline salaries for Site contractor employees are compared with average salaries for Colorado services sector employees in generally comparable positions (in areas where comparisons are possible) (CDLE 1994a). Employer-paid benefits such as insurance are excluded. In general, average salaries in technical sectors (e.g., secretary for a mining or manufacturing company) are higher than salaries for the same occupation in the services sector. The services and construction sectors have been chosen for comparison because most jobs in the state are in these sectors and employment in them is increasing.

Table 4.12-8. Site Contractor and Colorado Average Salaries—Base Case Conditions

Job Classification	1996 Salary of Site Contractor Employees	Annual Salary in Colorado Services and Construction Sectors (1994)
Crafts	$43,630	$25,884 to $32,139
Engineers	$60,808	$50,689 to $62,336
General Administrative, Clerical	$30,469	$16,177 to $23,942
Laborers	$35,418	$12,079 to $35,374
Managers & Supervisors	$73,864	$23,942 to $51,120
Administrative and Other Professionals	$53,950	$31,492 to $58,022
Operators	$42,857	No comparable figures
Scientists	$59,601	$39,257 to $47,022
Technicians	$67,589	$25,884 to $32,570
Guards	$34,443	No comparable figures

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In general, the greatest differential is within the lower skilled positions, such as crafts, general administration, clerical, and laborers (excluding firefighters), where Site contractor salaries tended to be higher.

Under base case conditions, Site engineers, scientists, and technicians comprised approximately 36% of the Site work force. These workers apply skills in high-technology fields such as environmental engineering, materials sciences, nuclear engineering, chemistry, and computer engineering. In the Denver Metropolitan Area, workers in these occupations comprised 5% of the area's total labor force (BBC 1994). The Site work force includes a relatively high concentration of workers skilled in high technology fields, but the metropolitan-area economy supports a substantial demand for these types of workers.

Demand for skills and experience with sophisticated technologies is generated by a broad range of companies in the Denver Metropolitan Area, such as Coors, Lockheed-Martin, Samsonite, and Storage Technology Corporation. In general, high technology based industries are expected to generate substantial growth and employment opportunities for workers with training and experience in high-technology areas (RFLII 1994b). Many of the skills possessed by Site engineers, scientists, and technicians are transferable to other existing and emerging industries in the Denver Metropolitan Area.

Six high technology based industries—the environmental industry, telecommunications, advanced structural materials, advanced medical equipment, advanced computers, and advanced manufacturing technologies—have been identified as likely to employ substantial numbers of workers with technological skills in the Denver Metropolitan Area (RFLII 1994a).

4.12.3 Local Economy

Local economic issues addressed in this section include the purchase of goods and services by the Site contractor and DOE and the demand for retail, office, and industrial real estate related to these purchases. "Local economy" refers primarily to the eight-county Denver Metropolitan Area.

The Site contractor and DOE not only employ workers at the Site but also purchase goods and services from local and non-local vendors and suppliers through subcontracts and purchase orders. In the CID, this type of activity is referred to as "purchases." Purchases include engineering and technological consulting services, tools, equipment, office supplies, and a wide range of other products and services. All references to purchases in the CID are expressed in constant 1994 dollars.

Direct purchases are those made by the Site contractor and DOE. Indirect purchases are those generated by spending in the surrounding communities by employees of the Site and its vendors. As shown in Table 4.12-9, 1994 baseline purchases made directly by the Site contractor and DOE in Colorado totaled an estimated $218.5 million. Indirect purchases in Colorado are estimated at $1.1 billion, for total direct and indirect purchases of approximately $1.3 billion. Purchases within the Denver Metropolitan Area account for 96% of the Site's purchases in the State of Colorado.

Table 4.12-9. Direct and Indirect Site Purchases in Colorado—Baseline Conditions

Purchases	Denver Metropolitan Area	Other Colorado	Total
Direct	$211,971,707	$6,575,768	$218,547,475
Indirect	$1,080,911,114	$50,126,640	$1,131,037,754
Total Purchases	**$1,292,882,821**	**$56,702,408**	**$1,349,585,229**

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As shown in Table 4.12-10, of the total $1.3 billion in estimated Site purchases made in 1994 in Colorado under baseline conditions, approximately 33% were retail trade purchases, 19% were for business and personal services, and 17% were wholesale trade purchases.

Table 4.12-10. Total Site Purchases by Industry in Colorado–Baseline Conditions

Standard Industrial Classification	Denver Metropolitan Area	Total Colorado
Agriculture, Forestry, Fishing, Mining	1.6	1.6
Construction	3.2	3.1
Manufacturing	7.1	7.0
Transportation, Utilities, Commercial	6.3	6.3
Wholesale Trade	17.1	17.2
Retail Trade	32.7	32.9
Finance, Insurance, Real Estate	10.0	10.0
Services	19.2	19.2
Government	2.8	2.7
Total (%) of Total ($)	**100.0**	**100.0**
Total ($)	**$1,292,882,821**	**$1,349,585,229**

The demand for retail, office, and industrial space fluctuates as companies grow and downsize. To estimate the amount of retail, office, and industrial space occupied by firms from which the Site and its vendors purchased goods and services, the CID used as standards 1) the average number of employees in various industrial sectors and 2) average statistics regarding square feet of space per employee.

As shown in Table 4.12-11, the Site generated demand for approximately 3.7 million square feet of private-sector retail, office, and industrial space in Colorado under baseline conditions (FRC 1995). Of this total, approximately 3.6 million square feet of space, or 96%, was in the Denver Metropolitan Area.

Table 4.12-11. Private Sector Demand for Nonresidential Space in Colorado–Baseline Conditions

Type of Space	Site Demand in Colorado (square feet)	Site Demand in Denver Metro Area (square feet)	Total Denver Metro Area (square feet)	Site Demand as Percentage of Metropolitan Area
Retail	1,841,240	1,762,065	67,032,900[1]	2.6
Office	1,155,402	1,107,403	72,519,500[2]	1.5
Industrial	730,160	701,632	135,861,900[3]	0.5
Total	**3,726,802**	**3,571,100**	**275,414,300**	**1.3**

[1]Retail space includes single-tenant and multi-tenant centers over 10,000 square feet.
[2]Office space includes single-tenant and multi-tenant buildings over 20,000 square feet. Owner-occupied, government and medical buildings, and retail space within office buildings are excluded.
[3]Industrial space includes single-tenant and multi-tenant buildings over 20,000 square feet.

To provide some perspective, estimates of total nonresidential space in the Denver Metropolitan Area are also listed. Actual nonresidential space is underestimated, as the survey accounts for space only in buildings which are over 10,000 square feet for retail space or 20,000 square feet for office space. With this limitation, the 3.6 million square feet of space occupied by businesses in the Denver Metropolitan Area that sell goods and services to the Site represented about 1.3% of total nonresidential space in the metropolitan area.

4.12.4 Population and Housing

A total of 11,809 households in Colorado were associated with the Site in 1994. Within these households, population totaled 28,395, or about 1% of the 1994 population in Colorado (3,665,647). Table 4.12-12 provides a summary of Site direct and indirect effects on households in the Denver Metropolitan Area and Colorado under baseline conditions (USBC 1993). Estimates of average salaries, average household income, and housing values are expressed in constant 1994 dollars.

Table 4.12-12. Site Direct and Indirect Effects on Households in the Denver Metropolitan Area and Colorado–Baseline Conditions

Parameter	Denver Metropolitan Area	Other Colorado	Total
Employees	15,782	751	16,533
Average Employees Per Household	1.4	1.4	–
Households	11,273	536	11,809
Average Persons Per Household	2.4	2.5	–
Total Population in Households	27,055	1,340	28,395
Average Salary: On-Site Employees[1]	$50,358	$50,346	$50,352
Average Salary: Off-Site Employees	$37,452	$37,130	$37,291
Average Salary: All Employees	$41,708	$41,576	$41,642
Average Household Income for All Households	$47,708	$45,576	$47,642
Average Housing Value[2]	$116,361	$116,039	$116,200

[1]On-site employees include the Site contractor's employees as well as DOE employees.
[2]Average housing value is calculated by dividing household income by 41%, consistent with the Bureau of Labor Statistics' *Consumer Expenditure Survey - 1990-91* (USDL 1993). It is assumed that one household occupies one housing unit.

As shown in the table above, Site workers earned an estimated average of $41,642 per year in 1994. The average household income for all Site-related households in Colorado (including secondary wage earners) is estimated at $47,642. This estimate is based on 1.4 Site employees per Site-related household and an average supplemental income for secondary wage earners of $15,000.

The average value of housing that these households could afford based on household income is estimated at $116,200. The ratio of household income to housing values was obtained from the *1990-1991 Consumer Expenditure Survey* prepared by the Bureau of Labor Statistics (USDL 1993).

4.12.5 Quality of Life

This section presents a discussion of quality of life in the Denver Metropolitan Area under baseline conditions. It excludes consideration of environmental and health-related issues, as these are addressed in other sections of the CID.

The analysis is based on 1) a review of existing literature describing the Site; 2) consideration of demographic, employment, and economic effects; 3) a review of documents prepared by other organizations regarding changes in Site mission; 4) interviews with planners and other officials; 5) a qualitative analysis of environmental stigma issues; and 6) an independent analysis of quality-of-life issues in the Denver Metropolitan Area (Adams 1991, BBC 1994, Belsten 1994, CDLE 1995a, EPS 1995, NCPP 1994a, Powell 1994a and 1994b, RFLII 1994a and 1994b, DOE 1995e, and USDL 1993).

Key factors that contribute to a high quality of life in the Denver Metropolitan Area include its moderate, four-season climate; proximity to wilderness, scenic, and natural amenities; abundance of recreational opportunities; and availability of nearby urban amenities, including upscale retail centers, professional sports teams, and cultural facilities such as theaters and museums. Recent trends and events in the metropolitan area have raised a number of quality-of-life concerns; most prominent among these are issues involving crime, air pollution, and a range of growth management issues, including traffic congestion, open space, and education.

Aside from environmental contamination issues, Site activities under baseline conditions do not notably influence quality of life in the Denver Metropolitan Area. Site activities are unrelated to factors such as climate or the recreational amenities available in the Rocky Mountain region. The work force at the Site helps support metropolitan area retail, recreational, cultural, and entertainment amenities but represents only a small percentage of the overall metropolitan-area market for these types of amenities.

Issues involving crime and security raise concerns in the metropolitan area, but there is no evidence that these bear any relation to the Site. Metropolitan-area air quality issues related to traffic and fuel consumption also bear little direct relation to the Site (Section 4.5, "Air," addresses potential environmental effects of Site-generated air emissions). The Site has not contributed to concerns over employment and population growth in the area in recent decades; operations at the Site have been ongoing since 1952, and the effects of this work force have been accommodated within the metropolitan-area infrastructure for more than four decades.

One pertinent quality-of-life issue in connection with baseline conditions involves the general perception of a potentially hazardous environmental condition attributable to the Site and its surroundings. Superfund sites and facilities included on the National Priorities list can stigmatize their surroundings, creating undesirable perceptions that harm a community's identity and sense of well-being. This "stigma effect" is distinct from actual physical environmental effects in that it involves public perceptions rather than actual conditions. While difficult to quantify, environmental stigma effects can range from tangible losses in property values to more intangible effects involving a community's self-image or a general sense of insecurity with regard to environmental health and safety.

Some stigma may be associated with potential environmental contamination from the Site. In a 1994 survey of residents living within 5 miles of the Site, respondents reported varying levels of concern regarding various types of activities and potential hazards at the Site: 48% of the respondents from the general public reported "neutral" impressions of the Site, 27% reported unfavorable impressions, and 25% reported favorable impressions (Belsten 1994). Other survey responses indicating a possible stigma effect are presented in Table 4.12-13. Similarly, former site contractors have been sued by land owners surrounding the site for alleged losses in property values reportedly caused by the stigmatizing effect of environmental and nuclear hazards emanating from the site.

Table 4.12-13. Survey Responses

Survey Question	Response	Percent of Responses
In your opinion, how much of a health risk does Rocky Flats pose to nearby communities? Would you say there's a:	High risk	4
	Moderate risk	30
	Low risk	30
	No health risk	12
	Don't know	24
In your opinion, to what extent does Rocky Flats pose a safety hazard to the surrounding community? Would you say you are:	Greatly concerned	4
	Somewhat concerned	20
	Concerned a little	34
	Not concerned at all	32
	No opinion at this time	10
Regarding the way Rocky Flats is managing its waste, would you say you are:	Greatly concerned	12
	Somewhat concerned	22
	Concerned a little	30
	Not concerned at all	24
	No opinion at this time	12
Regarding your proximity to Rocky Flats, would you say you are:	Greatly concerned	2
	Somewhat concerned	10
	Concerned a little	32
	Not concerned at all	54
	No opinion at this time	2

Overall, the survey respondents did not indicate widespread alarm regarding operations at the Site. It is possible, however, that some survey respondents were Site workers living within the 5-mile area who may therefore have a greater comfort level with the facility and its operations. The survey responses revealed that the general public living within 5 miles of the Site has some concern with regard to operations at the Site, resulting in a perception of a somewhat lower quality of life in this local population.

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4.13 Environmental Justice

Executive Order 12898, *Federal Actions to Address Environmental Justice in Minority Populations and Low-Income Populations*, was signed by President Clinton in February 1994. The order requires federal agencies to identify and address, as appropriate, disproportionately high and adverse health and environmental impacts of programs and activities on minority and low-income populations.

The executive order established "environmental justice," as a federal government priority and directed federal agencies to make environmental justice part of their mission. The executive order had three goals:

- Develop and implement an environmental justice strategy for each federal agency.
- Focus federal agency attention on environmental and human health conditions in minority populations and low-income populations.
- Provide minority populations and low-income populations greater access to information on, and opportunities for public participation in, matters relating to human health and the environment.

Executive Order 12898 directed each federal agency to review its programs, policies, and activities and develop a strategy for addressing any disproportionately high and adverse human health or environmental impacts on minority and low-income populations. In developing the strategies, agencies were directed to consider how their activities might be modified to:

- Promote enforcement of all health and environmental statutes in areas with minority and low-income populations.
- Ensure greater public participation in agency decision-making.
- Improve research and data collection relating to the health and environment of minority and low-income populations.
- Identify differential patterns of consumption of natural resources among minority and low-income populations.

Programs at the Site have been reviewed in light of these factors, and efforts taken to address the issues, as described below.

Site Response to Environmental Justice Directives

Executive Order 12898 directs federal agencies such as DOE to enforce all health and environmental statutes in minority and low-income areas in a non-discriminating manner and to identify disproportionate health impacts in such areas. No minority or low-income populations are located within a 10-mile radius of the Site, and no disproportionately high or adverse impacts have been identified from radiological or nonradiological ambient air emissions under baseline conditions for *any* segment of the population, including minority and low-income populations, since potential health impacts are well within regulatory levels.

To improve research and data collection relating to health and the environment, a health study known as the *Rocky Flats Toxicological Review and Dose Reconstruction Project* was conducted. The primary purpose of this project was to reconstruct potential doses of contaminants that might have been received by off-site individuals as a result of past Site operations. The study, conducted by CDPHE, was initiated to respond to public concerns that previous research on public health effects related to the Site had not provided enough data on exposures that had occurred. The Health Advisory Panel presented a preliminary health risk "best estimate" of approximately 1 chance of excess cancer in 100,000, based on an individual who had lived 37 years next to the Site. However, the health risk estimate for such an individual ranged from 1 in 1 million to 1 in 10,000 (CDPHE 1993b).

Identifying differential patterns of consumption of natural resources is not relevant to the Site because the Site is located in an urban area and the surrounding community does not engage in subsistence farming. According to the *Rocky Flats Toxicological Review and Dose Reconstruction Project,* the land surrounding the Site is not considered agricultural land due to the rocky, shallow conditions, and there is not a measurable game harvest (CDPHE 1993b).

Definition of Terms

Minority refers to people who classified themselves in the 1990 census as Black, Asian or Pacific Islanders, American Indians, Hispanics of any race, or other non-white individuals. For purposes of this document, *minority population* is defined as any census tract within a 50-mile radius of the Site (the "zone of impact") where minority individuals comprise 50% or more of the population. A census tract is an area defined for the purpose of monitoring census data that is usually comprised of between 2,500 and 8,000 persons, with 4,000 persons being ideal. In the case of migrant or dispersed populations, a minority population consists of a group that is greater than 50% minority.

Low-income population refers to a community experiencing common conditions of exposure or impact in which 25% or more of the population is characterized as living in poverty (EPA 1993a). The U.S. Bureau of Census characterizes persons in poverty as having income less than a "statistical poverty threshold." The 1990 poverty threshold for a family of four was a 1989 income of $12,674 (USBC 1992).

Region and Population Considered

The area considered for the environmental justice analysis was the region within a 50-mile radius of the Site. The eastern portion of the region is a relatively flat plain and largely privately owned. The western half of the region is mountainous and mostly government owned. For evaluation purposes, the region was subdivided into two sections: the area from 0 to 10 miles from the Site and the area between 10 and 50 miles from the Site.

The region includes 14 counties: all of Boulder, Clear Creek, Denver, and Gilpin Counties and portions of Adams, Arapahoe, Douglas, Elbert, Grand, Jefferson, Larimer, Park, Summit, and Weld Counties. Figure 4.13-1 shows the region analyzed and the distribution of counties within it.

Total population for the region was calculated by summing the populations of all the census tracts within the 50-mile radius (partial census tracts were calculated on a prorated basis). The majority of the population in the region is located within 30 miles of the Site. The populations of counties on the northern and western fringes of the study area (Grand, Larimer, Park, and Summit) make up only 9.8% of the total population for the 14-county region. Highest population densities are to the east of the Site, in a highly developed Broomfield subdivision, and to the southeast, where densities are as high as 5,200 persons per square mile. By comparison, the average population density for the total area analyzed is 263 persons per square mile. Within a 5-mile radius of the Site, the population is generally very low, and there are no residents within 2 miles of the facility (DOE 1995e). The total minority population within a 5-mile radius of the Site is less than 20% of the total population within that radius. Therefore, the population within 5 miles would not be considered a minority population, and it exceeds the statistical poverty threshold.

Minority Composition

The population of the 14-county region is above the national average for numbers of Hispanics, below the national average for Blacks, and near the national average for Asians and American Indians. The region's largest minority group is the Hispanic population. The City and County of Denver has the largest proportion of Hispanics, followed by Adams County, Jefferson County, and Arapahoe, Boulder, and Douglas Counties. The region's second-largest minority group, the Black population is concentrated in Denver and Arapahoe Counties.

Minorities make up 19.3% of the total state population but account for only 11.7% of the population in the 14-county region. The highest percentages of minorities within the region are in the Counties of Denver (38.5%), Adams (25%), Weld (22.6%), Arapahoe (14.6%), Boulder (10.5%), and Jefferson (9.9%). Table 4.13-1 shows minority population totals for each of the 14 counties analyzed and the State of Colorado as a whole. Data on minority demographics are based on 1990 U.S. Census information compiled and analyzed by the Denver Regional Council of Governments (DRCOG 1992).

Table 4.13-1. Minority Population by County

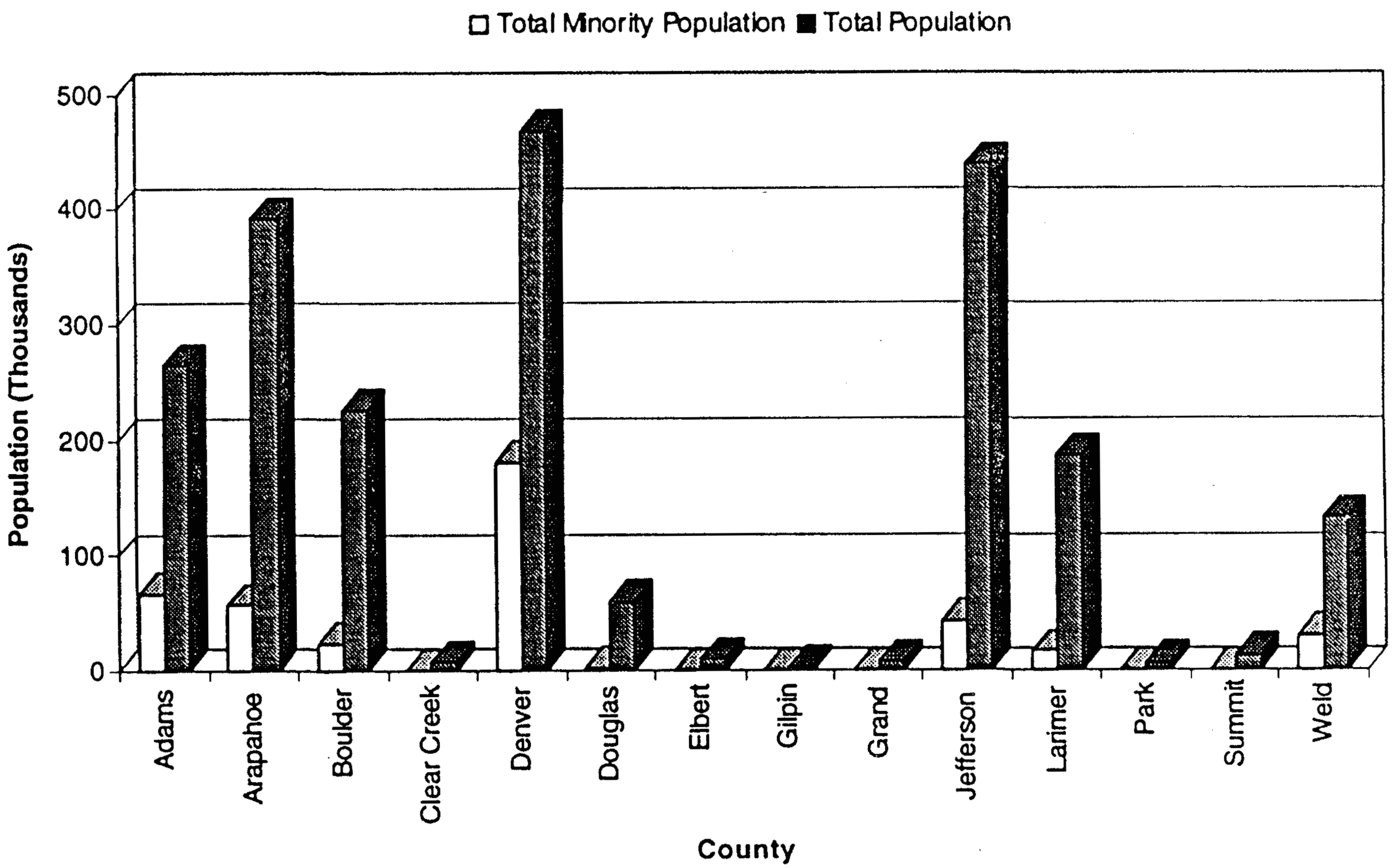
County	White	Hispanic Origin of Any Race	Black	Indian, Eskimo, or Aleut	Asian or Pacific Islander	Other Race	Total Minority Population	Total Population	Percent Minority
Adams	198,710	49,179	8,445	1,824	6,482	398	66,328	265,038	25.0
Arapahoe	334,225	21,743	22,653	1,790	10,796	304	57,286	391,511	14.6
Boulder	201,617	15,195	1,879	1,092	5,359	197	23,722	225,339	10.5
Clear Creek	7,280	254	17	26	39	3	339	7,619	4.4
Denver	287,162	107,382	57,793	3,761	10,159	1,353	180,448	467,610	38.5
Douglas	57,346	1,910	391	237	494	13	3,045	60,391	5.3
Elbert	9,289	211	46	57	42	1	357	9,646	3.7
Gilpin	2,900	109	14	34	13	—	170	3,070	5.5
Grand	7,641	243	16	28	37	1	585	7,966	7.3
Jefferson	394,946	30,791	3,014	2,019	7,365	295	43,484	438,430	9.9
Larimer	169,213	12,227	1,043	844	2,679	130	16,923	186,136	9.1
Park	6,863	206	39	45	15	6	311	7,174	4.5
Summit	12,359	323	31	69	94	5	522	12,881	4.0
Weld	101,977	27,502	509	393	1,063	377	29,844	131,821	22.6
State Total	**2,658,965**	**424,302**	**128,037**	**22,068**	**56,773**	**4,249**	**635,429**	**3,294,384**	**19.3**

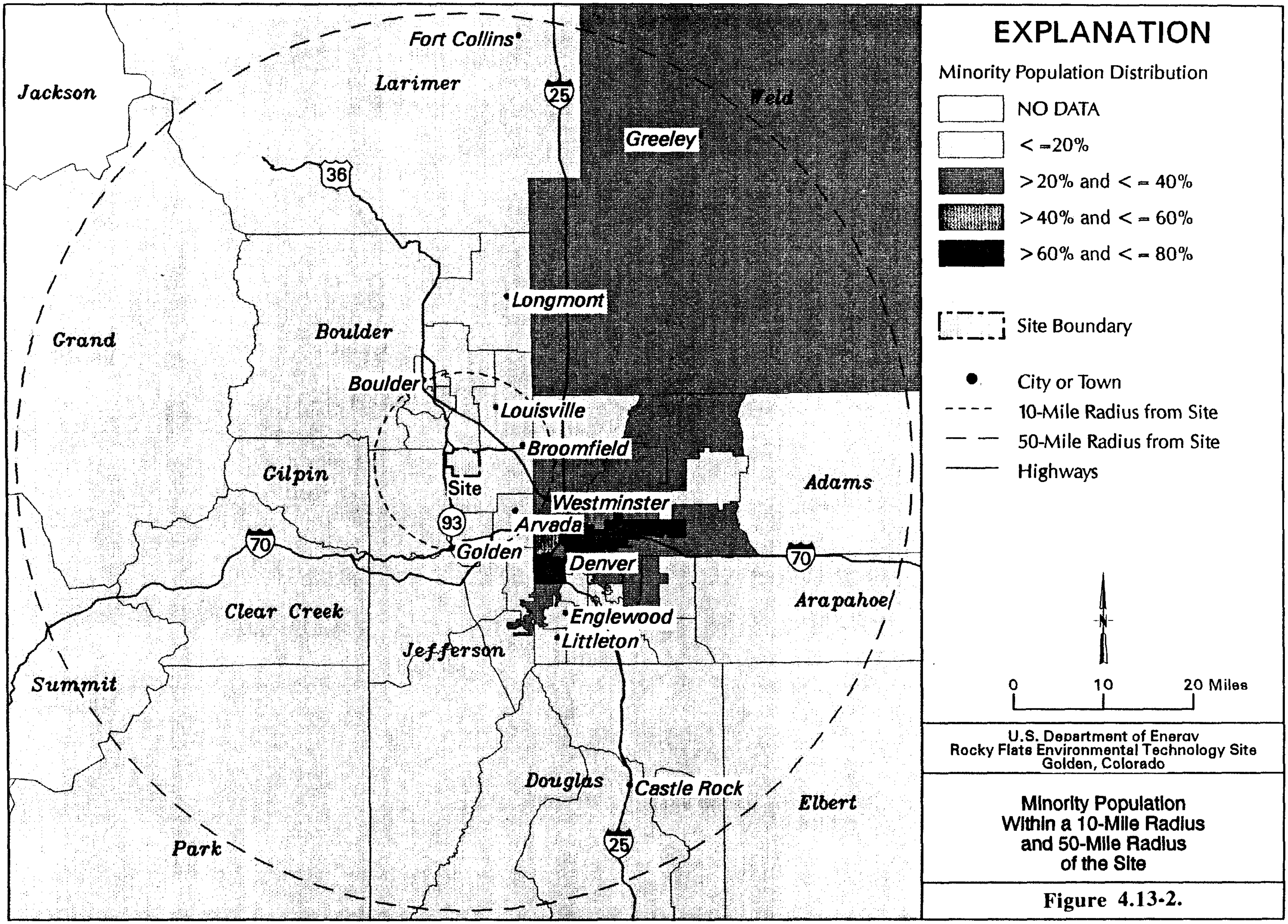
Figure 4.13-1 compares each county's total minority population to its total population. Figure 4.13-2 shows the distribution of minority residents within a 10-mile radius and 50-mile radius of the Site. As shown in this figure, the population within 10 miles of the Site is predominantly white. Between 10 and 50 miles of the Site, most of the minority population is concentrated in Denver County and western Adams County. The high concentration of minorities in these counties contrasts with the predominantly white communities of Boulder and Jefferson Counties and portions of Arapahoe County.

Low-Income Composition

The Denver area has been a relatively high-income area for a number of decades. In 1989, for example, this area had an average median household income of $33,124, which is 10% above the average median household income for Colorado and the United States. Figure 4.13-3 shows the median household income for the United States, the State of Colorado, the 14-county region analyzed, and the 14 counties individually, based on information reported in the 1990 U.S. Census.

Figure 4.13-1. Comparison of Minority Population to Total Population by County (1990 U.S. Census)



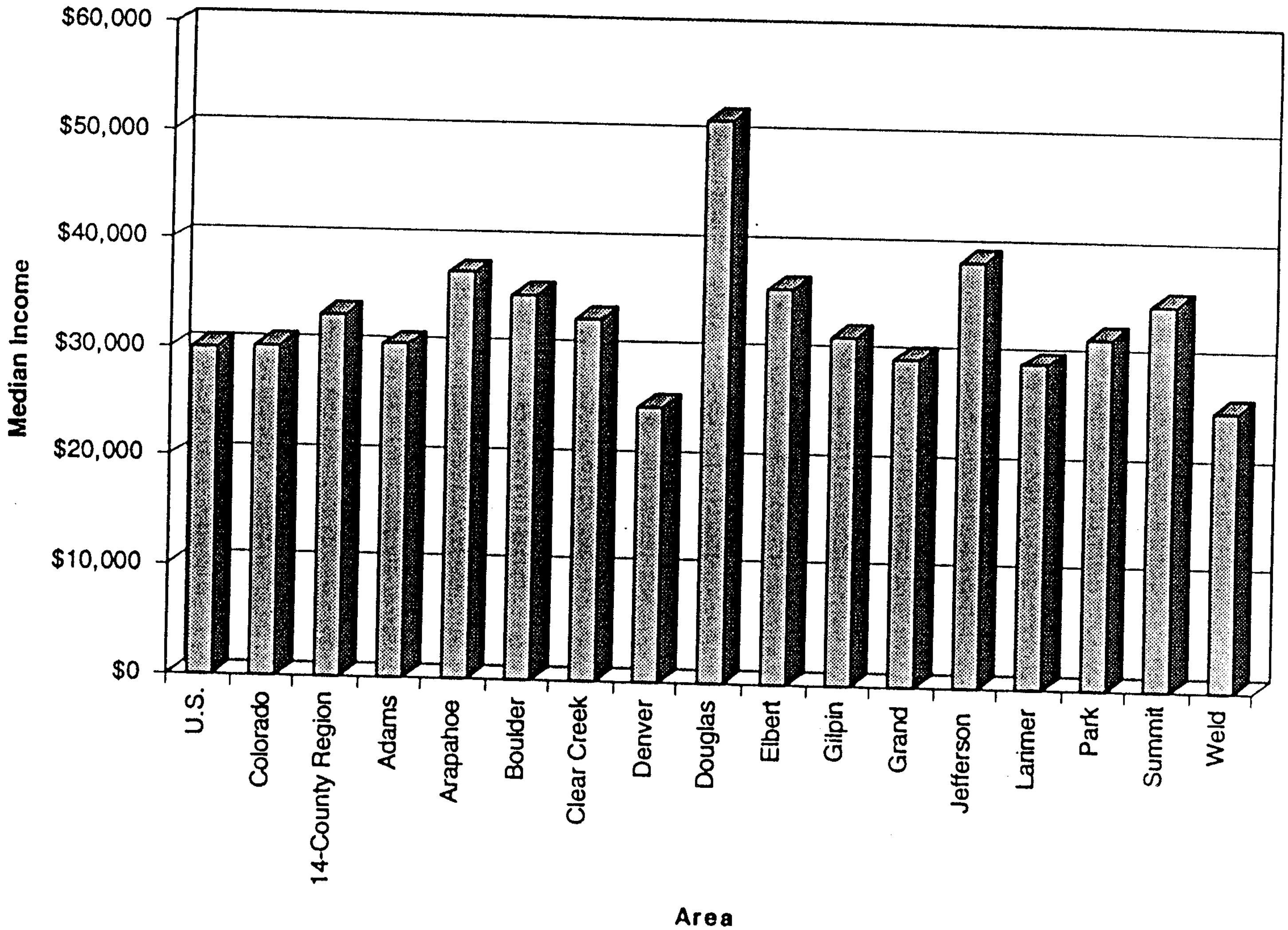


Minority Population Within a 10-Mile Radius and 50-Mile Radius of the Site

Figure 4.13-2.

25-JUN-1996 GRA: $DATA3/sweis/support/maps/minorplain.gra + AML: /home/data3/sweis/support/amls/rsabase.aml

Figure 4.13-3. Median Household Income



Within the region analyzed, Douglas County had the highest median household income at $51,718, which was 56% above the Denver-area median. The City and County of Denver had the lowest median household income at $25,106, which was 24% below the median. All median household incomes in all counties, however, were above the national poverty threshold of $12,674.

Table 4.13-2 lists each county's median income and percentage of families with income below the poverty level. As shown in the table, 7.8% of families within the 14-county area have median incomes below the poverty level. The highest percentages of low-income populations are in the Counties of Larimer (20.7%), Denver (13.1%), and Adams (8.8%). In Colorado as a whole, 8.6% of families have incomes below the poverty level. Therefore, the composition of low-income populations in the region analyzed is below the state average.

Table 4.13-2. Median Income and Percentage of Low-Income Populations by County

County	Median Income	Families With Income Below Poverty Level
Adams	$30,522	8.8%
Arapahoe	$37,234	4.4%
Boulder	$35,322	5.6%
Clear Creek	$33,149	6.1%
Denver	$25,106	13.1%
Douglas	$51,718	2.3%
Elbert	$36,273	5.7%
Gilpin	$31,898	7.1%
Grand	$29,991	4.8%
Jefferson	$39,094	4.1%
Larimer	$29,686	20.7%
Park	$32,102	6.7%
Summit	$35,229	8.6%
Weld	$25,642	10.6%
14-County Total	**$33,783**	**7.8%**
State Total	**$30,140**	**8.6%**

Figure 4.13-4 illustrates the patterns in median income within a 10-mile radius and 50-mile radius of the Site. Within the 10-mile radius, Adams, Arapahoe, Boulder, Gilpin, and Jefferson Counties exceed the national and state household median incomes. Areas with low median income are for the most part concentrated in Adams and Denver Counties. In contrast, portions of Arapahoe, Douglas, and Jefferson Counties have very high median incomes. Income for the remainder of the study area is near the median.

The identification of minority populations and low-income populations (Figure 4.13-5) surrounding the Site establishes the environmental justice assessment for baseline conditions.

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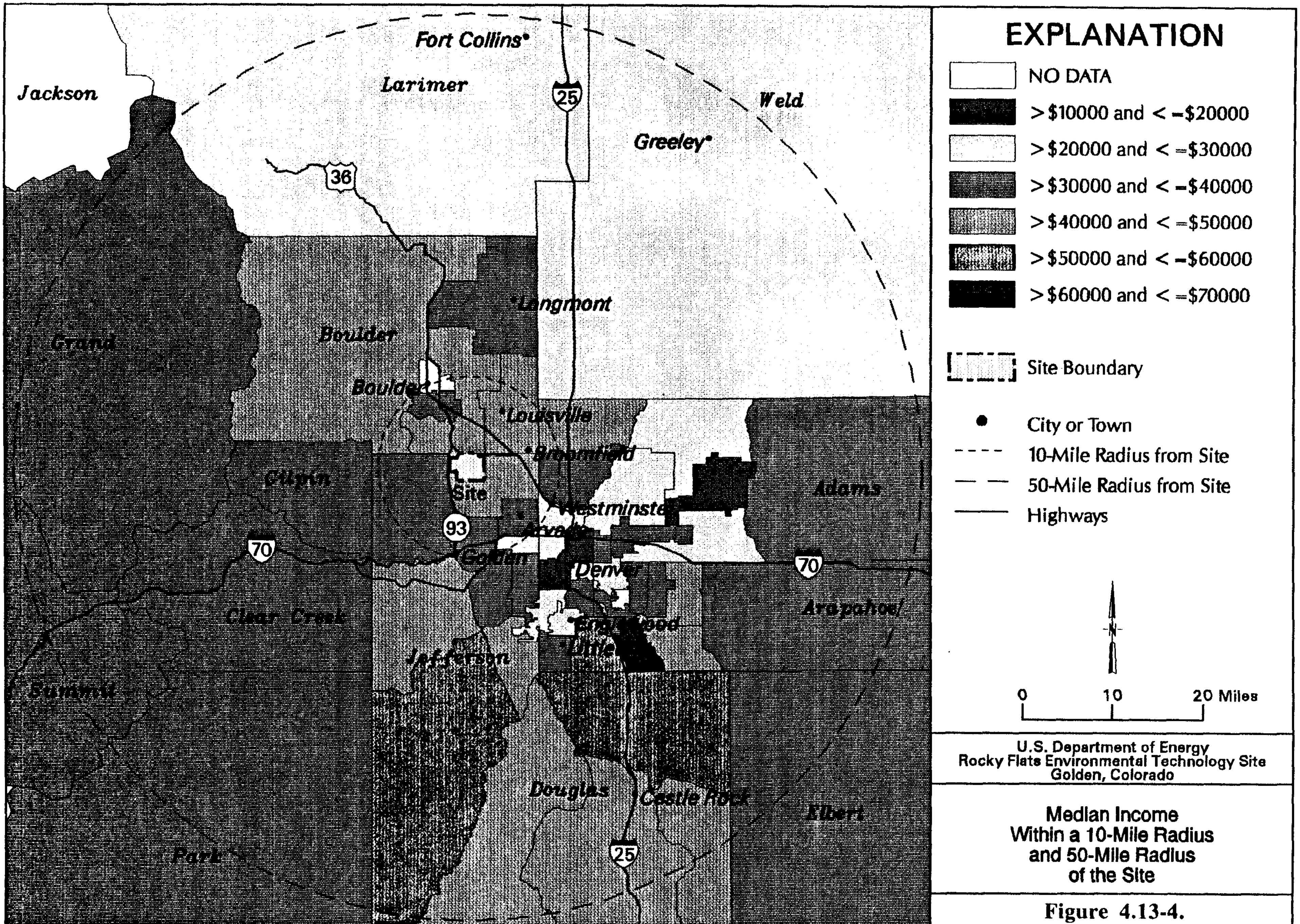

U.S. Department of Energy
Rocky Flats Environmental Technology Site
Golden, Colorado

Median Income Within a 10-Mile Radius and 50-Mile Radius of the Site

Figure 4.13-4.

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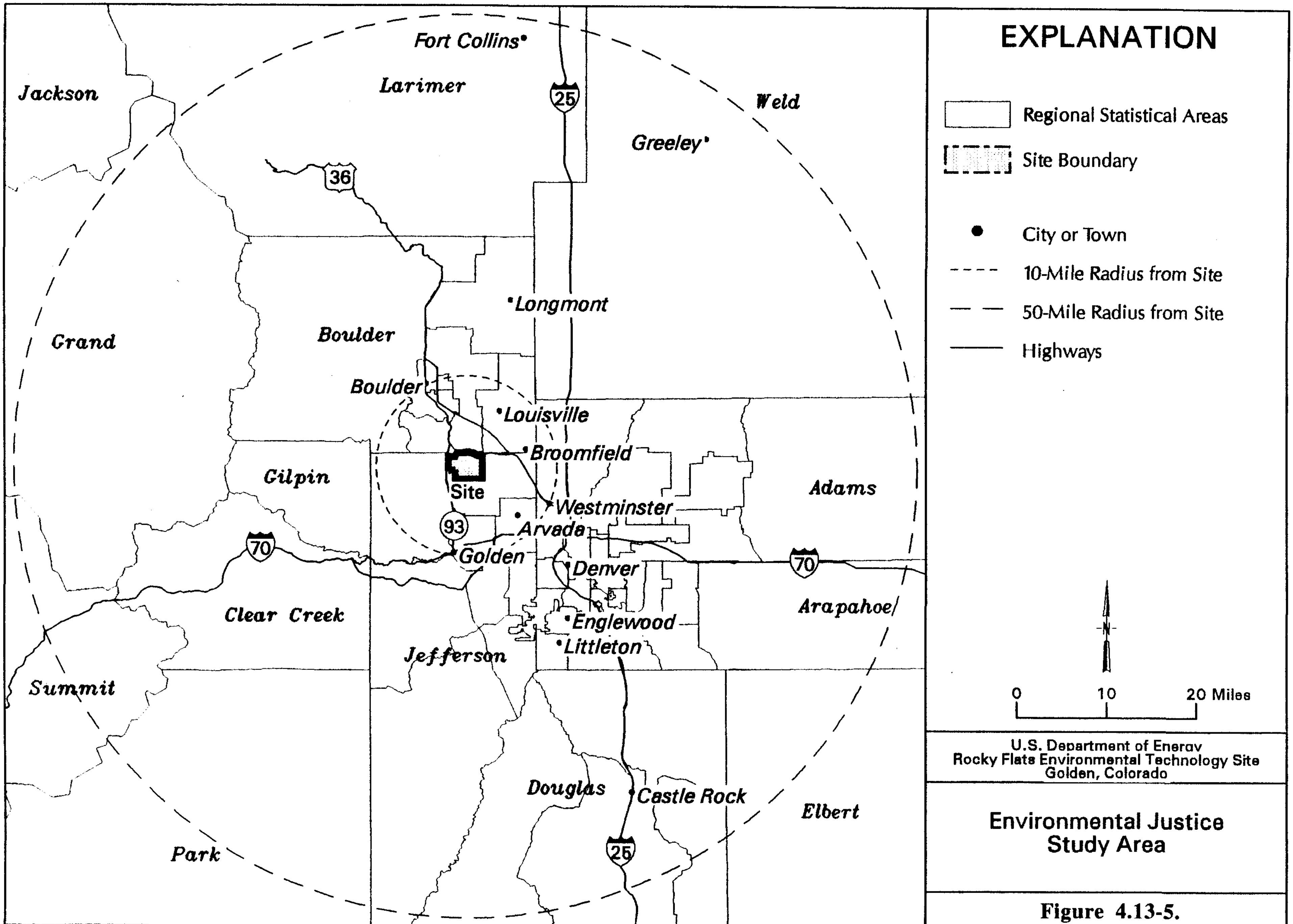

U.S. Department of Energy
Rocky Flats Environmental Technology Site
Golden, Colorado

Environmental Justice
Study Area

Figure 4.13-5.

25-JUN-1996 GRA: $DATA3/sweis/support/maps/rsabnd.gra • AML: /home/data3/sweis/support/amls/rsabnd.aml

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CHAPTER 5
ENVIRONMENTAL CONSEQUENCES

5.1 Introduction

Chapter 5 describes the potential environmental consequences at the Rocky Flats Environmental Technology Site (Site) and in the surrounding region that may result from implementing the two cases described in the Cumulative Impacts Document. The organization of Chapter 5 closely parallels that of Chapter 4, "Affected Environment," to facilitate comparison of *baseline* conditions and environmental impacts for each topic or discipline. At a more detailed level, each section of Chapter 5 is organized to provide the reader with 1) a brief summary of the types of impacts to be discussed, 2) a comparison table presenting the assessed impacts (qualitative or quantitative), and 3) text offering additional details or insights into the impacts analysis. This approach should enable readers to obtain the level of detail they desire, whether it be a general overview of a particular subject or a focused analysis. Chapter 5 also includes a discussion of cumulative impacts of the five major programs at the Site and incorporates the local and regional impacts.

Best management practices and other measures are identified in this chapter that might modify, lessen, or nullify adverse environmental effects. For the purposes of impact assessment, best management practices were assumed to be either customary actions associated with proposed activities or mandatory actions specified by law or regulation or agency directives that are designed to reduce adverse impacts. Therefore, if an adverse environmental impact occurs as a result of actions taken and normal construction practices, regulations, or executive orders mandate that such impacts be reduced, the environmental analysis assumes that best management practices were incorporated into the action unless otherwise indicated in the text. For example, if a remedial action requires removal of vegetation and topsoil in a given area, and best management practices dictate the replacement of topsoil and revegetation, the loss of vegetation is not considered a substantial impact and topsoil replacement and revegetation are not considered "mitigation measures". If residual impacts (those impacts remaining following implementation of best management practices) are substantial, "mitigation measures" would be required.

For impact assessment, computer models are frequently used to evaluate contaminant transport or diffusion and to estimate exposure concentrations at receptor locations. Various computer models were evaluated and selected for use depending upon the type of analysis (routine operations or accidents) and the type of contaminant (radiological or hazardous chemical). Models that were employed are discussed in the appropriate sections of this chapter.

Risk assessments tend to err on the side of conservatism; that is, the estimates of risk to human resources (Site workers and the public) and natural resources (air, water, soils, plants, and animals) are unlikely to be exceeded. Actual monitoring data on contaminant quantities and concentrations were used whenever possible, and the health effects of radiation were calculated based on bounding assumptions of exposure. Similar assumptions were used in calculating risks under hypothetical accident conditions, including selection of the most severe types of accidents for analysis.

To allow for a fair comparison between the *baseline* and *closure* cases, the same methods and data sources were applied to the extent appropriate in evaluating impacts under each case. Annual data (such as annual doses) are based on the calendar year.

Provided in Table 5.1-1 is a comparative summary of the two cases in terms of their expected environmental impacts and other possible decision factors. These impacts are discussed more extensively in subsequent sections of Chapter 5.

Table 5.1-1 Comparison Summary of Environmental Impacts Under the *Baseline* Case and *Closure* Case

Baseline Case	***Closure Case***
Geology • No impacts due to topographic recontouring. • No impacts due to geologic hazards. • No additional impacts on mineral resources.	**Geology** • Less than 100 acres disturbed. • Moderate impacts due to topographic recontouring. • Low impacts due to geologic hazards. • Low impacts on mineral resources due to facility and cap construction.
Soils • Continued loss of soil productivity in disturbed areas and Industrial Area. • No change in soil erosion. • No change in siltration.	**Soils** • Less than 100 acres would be remediated. Most remediated areas have been previously disturbed. • Small temporary loss of soil productivity due to remediation. • Moderate increase in long-term soil productivity. • Short-term increase in soil erosion due to remediation. Long term soil erosion stabilized after remediation. • Short-term increase in siltration due to remediation. Long term siltration stabilized after remediation.
Water • No impact on regional hydrogeology. • No impact on local hydrogeology. • No additional impacts on ground water quality. • Limited impacts on surface water quality. • Impact to surface water flows downstream of terminal ponds. • Potential for upset of Wastewater Treatment Plant or contaminant spill/release to impact surface water. • Present water management system impacts flows downstream of terminal ponds.	**Water** • No impact on regional hydrogeology. • Local surface and subsurface flowpath and infiltration changes. Reduction in open water habitat. Floodplains unaffected or improved. • Ground water quality improvement to meet risk-based standards for open space receptors. • Surface water quality improvement to meet risk-based standards for open space receptors. • Beneficial impacts to downstream surface water flows. • Change flow-through system would greatly improve flows below terminal ponds.
Ecology • Periodic impacts to wetlands and wildlife due to maintenance activities. • Continued encroachment of weeds and thatch build-up. • Habitats impacted by "batch-release" pond operations.	**Ecology** • Short-term impacts to vegetation, wetlands, sensitive habitats, and wildlife. • Successful reclamation/revegetation, implementation of best management practices and/or avoidance of sensitive habitats would result in low long-term impacts. • Relatively small loss of open water habitat. • Change to "controlled detention" pond operations will improve habitats downstream of terminal ponds.

Table 5.1-1 Continued
Comparison Summary of Environmental Impacts Under the *Baseline* Case and *Closure* Case

Baseline Case	*Closure Case*
Utilities and Energy • Baseline site water use is approximately 130 million gallons per year. • Steam usage is approximately 425 million pounds of steam per year. • Natural gas usage is approximately 640 million cubic feet per year. • Electricity usage is approximately 12.5 gigawatt-hours per month. • Nitrogen gas usage is approximately 125,000 cubic feet per hour.	**Utilities and Energy** • Decreased water usage due to decommissioning of facilities and reduced work force. Positive impact due to reduced usage. • Decrease in steam usage as facilities are decommissioned. Positive impact due to reduced usage. • Decrease in natural gas usage as facilities are decommissioned. Positive impact due to reduced usage. • Decrease in electricity usage as facilities are decommissioned. Positive impact due to reduced usage. • Decrease in nitrogen gas usage due to accelerated stabilization of SNM. Positive impact due to reduced usage.
Radiological Air Quality • Projected impacts to the maximally exposed individual would be well below the off-site standard of 10 millirem per year for the air pathway only.	**Radiological Air Quality** • Potential for increase in dose to the maximally exposed Individual due to SNM consolidation and environmental restoration activities. Projected impacts to the maximally exposed individual would be well below the off-site standard of 10 millirem per year for the air pathway only.
Nonradiological Air Quality -- Point Sources • All impacts below applicable ambient air quality standards and guidelines for criteria and toxic pollutants.	**Nonradiological Air Quality -- Point Sources** • Same as *baseline* except for minor differences for certain air toxic impacts. All impacts below applicable standards and guidelines for criteria and toxic pollutants.
Nonradiological Air Quality -- Fugitive Dust Sources • All impacts below applicable ambient air quality standards.	**Nonradiological Air Quality -- Fugitive Dust Sources** • Moderate increase in annual PM-10 and TSP concentrations due to environmental restoration activities. All impacts below applicable ambient air quality standards.
Cultural Resources • No adverse impacts	**Cultural Resources** • 100% increase in adverse impacts due to decommissioning and dismantlement of historic facilities
Socioeconomics • Presently approximately 6,700 direct employees at the Site	**Socioeconomics** • Gradual reduction in Site employment levels until Site closure when employment levels will include only monitoring personnel required for remediation commitments (< 25 people).
Local Traffic Impacts • Approximately 6,500 personal vehicles and fewer than 20 commercial trucks would enter and leave the Site each day. The average annual number of off-site shipments would be approximately 100. Traffic congestion at the entrance gates occurs only during shift change.	**Local Traffic Impacts** • Personal vehicle trips would decrease by approximately 50% per day as a result of reduced staffing levels. Approximately 100 commercial truck trips per day would be expected. The average annual number of off-site waste and environmental restoration shipments would be approximately 21,000. These trips would need to be timed to avoid peak traffic hours. Increased congestion at the entrance gates during shift changes would be expected, but would not be substantial.

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Table 5.1-1 Continued
Comparison Summary of Environmental Impacts Under the *Baseline* Case and *Closure* Case

Baseline Case	*Closure Case*
Routine Transportation Impacts (From Air Pollution annually) • Approximately 0.29 excess latent cancer fatalities would be expected from routine on-site transportation. • Approximately 1 excess latent cancer fatality would be expected from routine off-site transportation.	**Routine Transportation Impacts (From Air Pollution annually)** • Approximately 0.18 excess latent cancer fatalities would be expected from routine on-site transportation. • Approximately 0.9 excess latent cancer fatalities would be expected from routine off-site transportation.
Accident Impacts - Cancer Risk from Radiological Accident (annually) • Annual on-site transportation risks to the general public, the maximally exposed off-site individual, and the co-located worker would be approximately 5×10^{-7} latent cancer fatalities per year, 8×10^{-7} mrem per year, and 3×10^{-7} mrem per year, respectively. • Annual off-site transportation risk is 2×10^{-3} latent cancer fatalities per year.	**Accident Impacts - Cancer Risk from Radiological Accident (annually)** • Annual on-site transportation risks to the general public, the maximally exposed off-site individual, and the co-located worker would be approximately 1×10^{-6} latent cancer fatalities per year, 2×10^{-6} mrem per year, and 7×10^{-7} mrem per year, respectively. • Annual off-site transportation 1×10^{-1} latent cancer fatalities per year.
Fatalities from Collision • Annual estimated traffic fatalities from Site-related traffic would be 1.6, primarily due to worker commuting.	**Fatalities from Collision** • Annual estimated traffic fatalities from Site-related traffic would be 1.7, due to worker commuting and over-the-road shipments.
Radiological Impacts to Workers • Collective dose to the worker population was 263 person-rem/year (0.01 excess latent cancer fatality).	**Radiological Impacts to Workers** • Collective dose for workers would increase with increased SNM management, DD&D, and waste management activities to 417 person-rem/year (0.2 excess latent cancer fatality).
Radiological Impacts to Co-Located Worker • Maximum dose to the co-located worker would be approximately 0.29 millirem/year (1×10^{-7} increased cancer risk).	**Radiological Impacts to Co-Located Worker** • Maximum dose to the co-located worker would be approximately 5.4 millirem/year (2×10^{-6} increased cancer risk).
Radiological Impacts to the General Public • Dose to the general population would be approximately 0.27 person-rem/year (1×10^{-4} excess latent cancer fatality).	**Radiological Impacts to the General Public** • Dose to the general population would be approximately 23 person-rem/year (0.01 excess latent cancer fatality).
Radiological Impacts to the Maximally Exposed Off-Site Individual • Dose to the maximally exposed off-site individual from the air pathway would be about 0.0052 millirem/year (3×10^{-9} increased cancer risk).	**Radiological Impacts to the Maximally Exposed Off-Site Individual** • Dose to the maximally exposed off-site individual from the air pathway would be about 0.23 millirem/year (1×10^{-7} increased cancer risk).
Occupational Nonradiological Impacts • Illness and injury cases among Site contractor and subcontractor employees is estimated to be approximately 250 per year.	**Occupational Nonradiological Impacts** • Illness and injury rates would increase to approximately 580 cases per year. Number of cases would be highest under this alternative as a result of the high levels of activity, especially DD&D. However, cases would drop to very low levels towards the end of the CID timeframe.

Table 5.1-1 Continued

Comparison Summary of Environmental Impacts Under the *Baseline* Case and *Closure* Case

Baseline Case	*Closure Case*
Nonradiological Air Pollution Impacts • The hazard index, which is a conservatively calculated measure of potential risk, is 1.3. At this level there may be some cause for concern, however, due to contributions from off-site background conditions, this is not considered significant.	**Nonradiological Air Pollution Impacts** • The hazard index is calculated at 1.5. Risks from air pollution would be slightly higher than the *baseline* case, but is not considered significant.
Vegetation • Potential impacts due to weeds and buildup of thatch.	**Vegetation** • Disturbance to upland plant communities, including native grasslands, would result in low short-term impacts. • Successful reclamation would result in low long-term impacts.
Wetlands • Wetlands will have periodically impacts due to maintenance activities.	**Wetlands** • Disturbance to wetland habitat would result in short-term impacts. • Successful reclamation under U.S. Army Corps of Engineers regulations, as part of Site activities, would result in low long-term impacts.
Sensitive Habitats • Habitats below terminal ponds impacts by reduced flows due to "batch-release" pond operations.	**Sensitive Habitats** • Native grasslands, wetlands, and riparian woodland, would be disturbed. This would result in a short-term impact. • Avoidance of sensitive habitats, implementation of best management practices, and/or successful reclamation would result in low long-term impacts.
Wildfire • Impacted by maintenance activities.	**Wildfire** • Key receptor species habitat would be disturbed. This is considered a short-term impact. • Reclamation of affected areas and successful revegetation with native plant communities would result in low long-term impacts.
Aquatic Fauna • Impacted by reduced flows downstream of terminal ponds and maintenance activities.	**Aquatic Fauna** • Loss of open-water habitat would result in short-term impacts. • Change to "controlled detention" for pond operations will result in improved habitat below terminal ponds. • Some losses would be offset by establishment of additional wetland habitat, resulting in moderate long-term impacts.
Habitat for Species of Special Concern • Impacted by reduced flows downstream of terminal ponds and maintenance activities.	**Habitat for Species of Special Concern** • Approximately 183 acres would be disturbed. this is considered a short-term impact. • Change to "controlled detention" for pond operations will be improved habitat below terminal ponds. • Reclamation of affected areas and revegetation with native plant communities would result in low long-term impacts.
Biodiversity • Impacted by reduced flows below terminal ponds and maintenance activities.	**Biodiversity** • The major impact to regional biodiversity would be the loss of open-water habitat quality and relatively small area affected, impacts on biodiversity would be negligible.

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Table 5.1-1 Continued

Comparison Summary of Environmental Impacts Under the *Baseline* Case and *Closure* Case

Baseline Case	***Closure Case***
Cultural Resources • No additional adverse impacts anticipated and maintenance activities.	**Cultural Resources** • No additional adverse impacts anticipated.
Visual Resources • No impacts on visual resources and maintenance activities.	**Visual Resources** • Moderate impact on visual resources due to DD&D/environmental restoration activities.
Noise • No significant noise impacts from current operations - mostly due to commuter traffic.	**Noise** • Minor changes in noise levels. May potentially be a noticeable impact due to increased waste shipments, environmental restoration activities, and DD&D activities.
Socioeconomics • No impacts on socioeconomics. Direct and indirect employment levels would remain at 16, 533 people and maintenance activities.	**Socioeconomics** • Direct and indirect employment levels would decrease by 15, 634 people. Impact on socioeconomics of the Denver Metro Area and Colorado would be negated by projected economic growth.
Environmental Justice • No impacts and maintenance activities.	**Environmental Justice** • No impacts.
Radiological Accidents • Seismic events dominate risk to co-located workers and the public. This is due to the majority of SNM inventory being stored in buildings which are vulnerable to earthquakes. SNM would not be repackaged into more robust containers. Seismic events represent over 90% of the total baseline risks. • Co-located worker risk = 5.3 mrem CEDE per year or 2×10^{-3} latent cancer fatalities per year. • Maximally exposed individual risk = 4.3×10^{-2} mrem CEDE per year or 2×10^{-5} latent cancer fatalities per year. • 50-mile collective population risk = 5.5×10^{-3} latent cancer fatalities per year.	**Radiological Accidents** • After a slight increase in risk in the near term, there would be an overall reduction of accident risks for the co-located worker and public. Materials would be stored in robust containers in new, hardened storage facilities until shipped off-site for permanent disposal. Seismic events still dominates risk until plutonium holdup is removed. Then risk to the public is due to storage of wastes until shipped off-site. • Co-located worker risk = 5.4 mrem CEDE per year or 2×10^{-3} latent cancer fatalities per year. • Maximally exposed individual risk = 4.6×10^{-2} mrem CEDE per year or 2×10^{-5} latent cancer fatalities per year. • 50-mile collective population risk = 6.2×10^{-3} latent cancer fatalities per year.

5.2 Impacts on Geology

The following criteria were established to measure whether the impacts on geology were substantial or not. Examples of substantial impacts are geologic hazards (e.g., landslides or slumps) resulting from an action and loss of a large quantity of valuable mineral resources. There may also be impacts from geologic activity on Site activities (e.g., earthquakes). Potential impacts from earthquakes are discussed in Section 5.14, "Impacts Resulting from Potential Accidents" and Appendix C "Accidents."

Impacts on geologic resources were assessed qualitatively by postulating likely geologic impacts from activities defined under the *closure* case.

Impacts on geologic resources at the Site would be minor to nonexistent for both of the cases. None of the identified impacts are substantial. Although the acreage disturbed in the *closure* case is large, the depth of disturbance is shallow and unlikely to cause impacts on geology. The identified impacts include the following:

- A minor potential exists for localized landslides or subsidence (slumping) to occur as a result of construction or excavation activities.
- A remote potential exists for inferred seismic faults to be exposed during excavation.
- The only likely geologic impacts would be to topography: 1) recontouring of soils and 2) some sand and gravel deposits may potentially be more difficult to access due to facility or cap construction.[1]

Table 5.2-1 summarizes the impacts on geologic resources potentially resulting from the major activities for each alternative. In all cases, comparisons are to *baseline* conditions.

Table 5.2-1. Impacts on Geologic Resources

Description	*Baseline Case*	*Closure Case*
Approximate Acreage Disturbed	Less than 5 acres	Less than 100 acres
Topographic Recontouring	Negligible	Moderate
Landslides and Subsidences	Negligible	Low
Exposure of Inferred Faults	Negligible	Low
Impacts on Mineral Resources	Negligible	Low

[1] *The surface estate for the property description of the Rocky Flats Technology Site is owned by the federal government. The subsurface or "mineral" estate, however, is owned by the federal government as well as a variety of private individuals. The majority of the subserface estate is not owned by the federal government.*

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5.3 Impacts on Soils

The main measure of soil productivity at the Site is the quantity and quality of vegetation growing in the soil and the extent that the vegetation supports ecological diversity and wildlife habitat. An evaluation of impacts on ecological resources, including vegetation and wildlife, is presented in Section 5.9, "Ecological Resources". The following impacts on soil may be considered substantial: 1) increased erosion, reduction in soil productivity, and reduction in stability prevents successful restoration and recovery to *baseline* conditions or better for greater than 10% of existing undisturbed areas; or 2) siltration increased to a level that substantially affects water quality or aquatic habitats.

To assess soil impacts, the acreage of affected soils was calculated for the *closure* case, and the impacts on different soil types within that acreage were evaluated (see Figure 4.3-1 for soil types present at the Site). The presence of contaminants above open space standards does not necessarily impact the soil productivity. The degree of disturbance and the presence of non-native species are a better measure of soil productivity. Areas that are remediated must be reclaimed by recontouring if necessary, addition of topsoil, and revegetation. Revegetated areas will require monitoring and maintenance (erosion control, regrading, and reseeding). Control of noxious weeds within revegetated areas may be required. Return of undisturbed areas to *baseline* conditions after remediation may take several years.

Table 5.3-1 presents the assessed impacts on Site soils.

Table 5.3-1. Impacts on Soils

Activity/Issue of Concern	*Baseline Case*	*Closure Case*
Acres Disturbed	• Less than 5 acres	• Less than 100 acres
Soil Productivity	• Low impact • Continued loss of soil productivity in disturbed areas and the Industrial Area	• Low additional impact • Most remediated soils are already disturbed. • Small temporary loss of soil productivity due to remediation • Moderate increase in long-term soil productivity due to Site remediation to open space and industrial standards within the two cases timeframe (beneficial effect)
Soil Erosion	• Low impact	• Short-term increase due to remediation. Long term impact stabilized after remediation.
Siltration	• Low impact	• Short-term increase due to remediation. Long term impact stabilized after remediation.

5.4 Impacts on Water

Potential impacts from the *baseline* and *closure* cases on surface and subsurface water resources include impacts on regional and local hydrogeology, impacts on ground water quality, and impacts on surface water quality. Potential impacts include alteration of flow volumes or flow paths, negative changes in floodplain capacities, and degradation of surface water quality or ground water quality with respect to applicable standards. These impacts would be caused by activities including excavation or treatment of contaminated soil and buried waste, removal of buildings and pavement, construction and operation of waste storage and disposal cells, construction of impermeable caps, and reduction or cessation of certain Site operations. This section describes the methodology for assessing impacts on the surface and subsurface water resources, describes activities that may impact water resources for each alternative, and provides a comparative impact assessment for the *baseline* and *closure* cases for regional and local hydrogeology, ground water quality, and surface water quality.

For each case, activities that may impact water resources are described and the impacts are assessed. A summary of the comparative impact assessment is presented in Table 5.4-1.

Table 5.4-1. Impacts on Water Resources by the *Baseline* and *Closure Case*

Description	*Baseline Case*	*Closure Case*
Regional Hydrogeology	None	None
Local Hydrogeology	None	Local surface and subsurface flowpaths and infiltration changes. Activities would result in Walnut Creek drainage being much dryer than it currently is. Area of pond habitat will be reduced. Wetland habitat may be affected, although engineering controls will maximize viability of wetlands. Net impact is uncertain. Floodplains unaffected or improved.
Ground Water Quality	Shallow groundwater is contaminated at many locations.	Water quality improvement to meet risk-based standards for open space receptors.
Surface Water Quality	Limited quality degradation. High potential for water depletion due to evaporation.	Water quality improvement to meet risk-based standards for open space receptors. Reduced water depletion potential because water is not retained for significant periods of time. More water available downstream.

Methodology for Assessing Impacts on Water Resources

Impacts on water resources are considered substantial if flow paths or flow volumes are altered to an extent that changes the nature of the water resource or water quality, any surface water or ground water quality standards are violated, annual sediment loads in streams increase more than one percent, floodplain characteristics are changed so that flood flows are impeded, or any other violation of Executive Order 11988 (protection of floodplains). To assess the impacts on water quality at the Site, ground water and surface water information was examined for the areas affected by each case. For regional hydrogeology, this information included the extent of the regional ground water system and the water-yielding characteristics of regional aquifers. For local hydrogeology and ground water quality, available ground water information included potentiometric surface maps, plume maps, cross-sections, geological logs, hydrographs, and pump test, slug test, and drawdown recovery test data. Potential impacts for both regional and local hydrogeology include increased or decreased recharge and infiltration, increased ground water extraction, and changed subsurface flowpath conditions.

For ground water quality, potential impacts include improved or compromised water quality associated with remediation activities under the *closure* case. Remediation activities most likely to impact ground water quality are of two types: 1) disposition of potential source materials by removal, treatment, isolation, and 2) actual treatment of ground water and surface water.

To assess the impacts on surface water quality, surface water information was examined for the areas affected for each case. This information included water quality data, flow data, and water level data for seeps, streams, and ponds. Three main factors affect surface water flow rates and surface water quality at the Site:

- Seeps are discharge areas for ground water and thus reflect ground water quality (if ground water is contaminated, then seep water will be contaminated). Seeps are prevalent in all the major drainages at the Site. Discharge of contaminated ground water to seeps may result in degradation of surface water quality.
- During a runoff event (snowmelt and rainfall), contaminated soils at the Site may be mobilized through erosion and transported into the stream channels. Contaminant concentrations within Woman Creek and Walnut Creek are typically greatest during runoff events (EG&G 1994h).
- The flow rate and effluent quality of the waste water treatment plant have a major impact on water quantity and quality in the South Walnut Creek drainage.

Impacts on surface water quality were evaluated based on the potential for seeps to be a source of surface water contamination, the availability of contaminated soils for erosion, and the disposition of the waste water treatment plant.

The two cases were compared in terms of the total area impacted, changes to ground water and surface water conditions in areas of surface impacts, and the types of effects. A summary of these impacts is presented in Table 5.4-1.

Description of Activities that Impact Water Resources

Activities on-site that may impact water resources include: 1) excavation or treatment of contaminated soil and buried waste, 2) construction of buildings, 3) removal of buildings and pavement, 4) construction and operation of waste storage and disposal cells, 5) construction of impermeable caps, and 6) reduction or cessation of certain Site operations.

Excavation of contaminated soil or buried waste is expected to locally increase runoff and erosion over the short term but have little impact over the long term. Large-scale excavations may impact surface water flowpaths and infiltration to an extent that causes measurable localized differences in ground water saturated thicknesses and flows. These ground water impacts would be most noticeable in areas of shallow depths to water table and small saturated thicknesses. Treatment of soil or buried waste would reduce loadings of contaminants to ground water and would locally alter flowpaths and reduce infiltration if the treatment reduces the hydraulic conductivity of the treated media.

Construction of buildings would have localized impacts on surface water flowpaths and ground water flowpaths and would locally reduce infiltration. Removal of buildings and pavement would locally decrease runoff and potentially increase erosion. Excavation may intersect the ground water table but should have little impact on flowpaths beyond the immediate area. During initial construction and operation (filling) of waste storage and disposal cells, impacts would be similar to the impacts for soil excavation.

Caps cause changes in surface water flowpaths, increase surface water runoff associated with precipitation events, virtually eliminate infiltration, decrease ground water saturated thicknesses beneath the cap, and decrease ground water flows out of the capped areas. Subsequently, reductions in downgradient seep flows may be observed. This may result in drier conditions in Site drainages and may have an impact on the wetland habitat currently existing at the seeps.

Cessation of Site activities that currently result in discharges to surface water or ground water would reduce surface water and ground water flows and potentially could reduce contaminant loading to surface water and ground water. The reduction in contaminant loading would be a beneficial impact. The reduction in surface water and ground water flows may have an impact on wetland or open water habitat in the Site drainages. For additional information on impacts to wetlands, see Section 5.9, "Impacts on Ecological Resources."

Off-site activities by outside interest can have an impact on the Site water resources. The cumulative impacts to the water resources in the region depend on the level of impact of off-site development projects.

Impacts on Regional Hydrogeology

Several characteristics of the regional ground water system are pertinent to the impacts assessment evaluation. The Denver Ground Water Basin underlies approximately 6,700 square miles extending from the Front Range of the Rocky Mountains east to Limon and from Greeley south to Colorado Springs. The Site is located on the northwest margin of this basin, and covers approximately 10 square miles (see Figure 4.4-4).

The water-yielding characteristics of an aquifer depend on the saturated thickness, the hydraulic conductivity (the ability of a unit volume of aquifer to transmit water), and the storage coefficient or specific yield (volume of water yielded for a unit drop in water level; storage coefficient refers to confined aquifers and specific yield refers to water table aquifers) of the aquifer materials. Within the Denver Basin, saturated thicknesses of alluvial materials range from more than 100 feet along the South Platte River to less than 20 feet at the Site. Sands with high hydraulic conductivity predominate along principal streams and creeks east of the South Platte River. Rocky Flats Alluvium contains a much larger percentage of silt and clay than occurs in the stream deposits, resulting in lower hydraulic conductivity. Specific yields at the Site and near the South Platte River are expected to be similar, although somewhat lower at the Site because of the presence of silt and clay. Due to the differences in saturated thicknesses, hydraulic conductivities, and specific yields, the South Platte River portion of the basin system contributes substantially more to the regional alluvial aquifer than the northwest portions, including the Site.

Hydraulic conductivities of the deeper aquifers beneath the Site, the Laramie-Fox Hills Aquifer and the Arapahoe Aquifer, are more than an order of magnitude less than the hydraulic conductivities of these same aquifers elsewhere in the Denver Metropolitan Area (Robson 1981). The Denver and the Dawson Aquifers also contribute to the Denver Basin system but are not present at the Site. Several hundred feet of low permeability confining layers (the lower aquitard) separate the Laramie-Fox Hills Aquifer and the Arapahoe Aquifer from the uppermost aquifer at the Site. Previous investigations indicate that the uppermost aquifer is not hydraulically connected to those bedrock aquifers.

The conclusion for both the alluvial aquifer and for the deeper aquifers is that contributions from the Site area to the regional ground water basin are minimal. For both cases, remediation activities are expected to have a negligible impact on regional hydrogeology.

Impacts on Local Hydrogeology

Local hydrogeologic conditions are described in Section 4.4.1, "Ground Water Characteristics." The conditions described there are pertinent to the assessment of impacts. Based on the hydrologic conditions described in Section 4.4.1, "Ground Water Characteristics," the activities described in the two cases are expected to impact only the uppermost aquifer at the Site. Based on the regulatory, as well as technical, definitions of an aquifer, the upper ground water flow system at the Site is not an aquifer because the yield of water to wells is typically low and broad areas of the system are unsaturated during the fall and winter (DOE 1995a). Well yields at the Site are insufficient to support domestic or residential water use. There is currently no consumptive use of ground water at the Site. However, for purposes of this document, the alluvial materials and weathered bedrock at the Site are defined as the uppermost aquifer (defined as the upper hydrostratigraphic unit in most Site documents).

The effect on wetland habitat is uncertain. The existing ponds will be recontoured to maximize the viability of the wetland habitat. For additional discussion on aquatic and wetland habitat, see Section 5.9, "Impacts on Ecological Resources."

BASELINE CASE. Impacts on Site hydrogeology would be minimal since minor remedial activities have occurred, and very little facility deactivation, decontamination, or decommissioning has taken place.

CLOSURE CASE. Activities under this case would affect Site surface hydrology, resulting in secondary impacts on subsurface hydrology. Caps would locally prevent recharge to the alluvial ground water and construction would require engineered water management, such as footing drains and diversion ditches. Construction activities and the removal of building foundations within the Industrial Area but outside of the Protected Area may intercept the local shallow ground water system. The impact of construction activities and the removal of building foundations is expected to be minimal with respect to Site ground water flow. The large cap over the existing Protected Area may have an impact on seep areas in the North Walnut and South Walnut Creek drainages. The cap would reduce the infiltration to ground water and increase the short-term surface water flows in the drainages in response to precipitation events. The reduced infiltration would result in reduced flows to seeps in the North Walnut and South Walnut Creek drainages. The cap over the 800 Building Complex would have a lesser impact on seeps in the Woman Creek drainage because of the smaller size of this cap.

Two other changes under the *closure* case would result in reduced flows in seeps, streams, and ponds. The closing of all existing buildings and the shutdown of the existing water distribution system would result in an annual reduction to ground water recharge of up to 18 million gallons (USGS 1995). This is the estimate of losses from the system. This reduction in infiltration to ground water would result in reduced flows to seeps in the North Walnut and South Walnut Creek drainages. In addition, the Site sewage treatment plant discharges 54.7 million gallons annually to South Walnut Creek drainage. The proposed closing of this system and the transition to a zero-discharge lagoon system would result in reduced flows to the South Walnut Creek drainage and may impact the viability of wetlands and pond habitats. The sewage treatment plant contributes approximately 60% of the yearly flow in South and North Walnut Creeks combined. The Walnut Creek discharge at the Site boundary contributes approximately 70% of the entire off-site discharge (EG&G 1994h).

Impacts on local hydrogeology from these activities are substantial because the reduced flows in the North Walnut and South Walnut Creek drainages will alter the character of the drainages. The contributors to these reductions in flows, in order of decreasing importance, are the closure of the Site sewage treatment plant, the shutdown of the existing water distribution system, and the placement of impermeable caps. This change will return the drainages close to their natural state, but this will likely lead to reduced aquatic habitat.

Impacts on Ground Water Quality

This section discusses impacts on ground water quality associated with the two cases. This information shows that shallow, alluvial ground water is contaminated with volatile organic compounds, metals, radionuclides, and nitrates at certain locations across the Site and local detections in the bedrock ground water of the same analytes exist. The selection of remedies for ground water is part of the Rocky Flats Cleanup Agreement process. The *closure* case description includes remediation to open space standards and relies on the RFCA process to define the steps necessary to meet these standards.

Activities under the *baseline* case would result in the worst Site ground water quality, and the potential would exist that risk-based standards for open space use would potentially not be met in some areas. Ground water quality would meet open space standards at the completion of remediation activities under the baseline case.

Impacts on Surface Water Quality

Each case would have a different effect on surface water quality. Current surface water operations ("batch release") and surface water quality are discussed in Section 4.4.4, "Surface Water Quality." The proposed method under the *closure* case for discharging water off-site is to operate the terminal ponds in a "controlled detention" mode. An off-site discharge of water using controlled detention is defined as a configuration with water flowing into a pond at the same time that water in flowing out of that pond and off the Site. The inflow and outflow rates are controlled to achieve an established efficiency for removing contaminants from the water. Because controlled detention may be operated continuously for several months, it is advantageous to utilize gravity, versus pumps, to remove water from the ponds. Transition to controlled detention will be achieved incrementally using a phased approach based on future Site conditions and Stakeholder approval.

The Site's transition plan for modifying operations and management of the on-site surface water detention ponds is documented in the Pond Operations Plan (POP). The modified operation phases will result in ecological benefits, increased stormwater detention capacity, dam safety enhancements, and more effluent use of Site funds while maintaining water quality.

Activities that may potentially impact surface water quality include soil remediation activities, pond water management practices including treatment and discharges, surface water structure maintenance, and waste water treatment plant effluent volume and quality.

Activities under the *baseline* case would result in the worst Site surface water quality, and risk-based standards for open space use may not be met in some areas. Surface water quality would meet open space standards at the completion of remediation activities. Closure of the Site Waste Water Treatment Plant will stop discharge of treated effluent to the Walnut Creek drainage.

The potential beneficial impacts of "controlled detention" include:

- Improved stormwater management through increased attenuation capacity;
- Improved dam safety by lowering average pool levels in the ponds;
- Pollutants controlled from being released off-site;
- Increased spill containment capacity; and;
- Enhanced aquatic resources and habitat downstream from the ponds by allowing a continuous off-site discharge to occur versus the sporadic release of water that results from "batch release" operations.

Controlled detention operations are described in greater detail in the Pond Operations Plan: Revision 2 dated September, 1996. (DOE, 1996n)

5.5 Impacts on Air

The impacts on air quality under the *baseline* and *closures* cases from radiological and nonradiological air emission sources are detailed in the following subsections. Specific assumptions and methodologies used to assess impacts are outlined within each subsection. The estimated air quality impacts obtained through modeling of the Site emission sources are compared to health-based standards or guideline concentrations for both on-site and off-site receptors. Air quality impacts are considered substantial when modeled results exceed the applicable standard or guideline concentration for the pollutant-of-concern.

5.5.1 Radiological Impacts on Air Quality

This subsection identifies and evaluates the radiological impacts on air quality for the *baseline* and *closure* cases. Radiological impacts are evaluated in terms of effective dose equivalent. Effective dose equivalent is estimated by using conservative source term estimates (quantity, timing and chemical/physical characterization of a contaminant) together with an approved air dispersion modeling code. Impacts are analyzed for co-located workers, a maximally exposed off-site individual at the Site boundary, and the public residing within a 50-mile radius of the Site. Estimated annual doses resulting from the *baseline* and *closure* cases, together with associated standards, are presented in Table 5.5-1.

Table 5.5-1. Estimated Annual Dose Associated With *Baseline* and *Closure* Cases

Dose Estimates	*Baseline Case*	*Closure Case*	Radiological Dose Standard
Co-Located Worker	0.29 millirem	5.3 millirem	5000 millirem[1]
Maximally Exposed Individual	0.0052 millirem	0.23 millirem	10 millirem[2]
Population[3]	0.270 person-rem	22.9 person-rem	–

[1]The radiological dose standard presented includes all exposure pathways. This standard is from 10CFR835.
[2]This standard is from 40 CFR 61, Subpart H, "National Emission Standard for Hazardous Air Pollutants" (NESHAP).
[3] These are effective dose equivalents projected for the population (approximately 2.7 million in 2006) within 50 miles of the Site.

The major features of the *closure* case include excavation of contaminated soils (inside and outside of the Industrial Area), point source emissions from soil treatment facilities, residue treatment, and building emissions associated with an accelerated schedule for consolidation and stabilization of SNM and residues. Also encompassed are emissions from DD&D of all existing buildings.

For both the *baseline* and the *closure* case, the calculated dose to the maximally exposed individual from the air pathway is small compared to the background radiation dose of 418 millirem per year. In addition, these calculated doses are well within DOE guidelines for protection of the public and the EPA annual dose limit (10 millirem) for airborne releases under the National Emission Standards for Hazardous Air Pollutants (NESHAP) (40 CFR 61, Subpart H). Therefore, the overall radiological air quality impacts are not substantial. These estimated doses are also lower than the National Council on Radiation Protection and Measurement's negligible individual risk level of 1 millirem per year (NCRP 1987c).

A more detailed description of worker and public health and safety and the relationship of airborne exposures to other exposures is presented in Section 5.8 "Impacts on Human Health and Safety."

Methodology Overview

Guidelines for estimating radiological air impacts established under NESHAP were followed throughout this analysis. As a measure of good practice and consistency with past emission reports, the methodology previously utilized at the Site was implemented for the radiological emissions analyses.

Estimates of radiological air quality impacts were developed in a conservative manner so that projected dose estimates would create an upper bound. The types of emission sources include point sources from building stacks and area sources from soil resuspension. The two major differences from the *baseline* are 1) the addition of radioactive air emissions from environmental restoration operations and 2) the inclusion of estimated radioactive source terms used for project-specific environmental assessments. The operations covered by the environmental assessments include actinide solution processing, residue treatment, and SNM stabilization and consolidation.

A geographical information mapping system was used to sum the dose results from dispersion modeling of radiological releases from a variety of sources. This is particularly useful for addressing consequences to co-located workers because dose consequences arise from many sources.

Comparative Impacts Assessment

The impacts associated with the *baseline* and *closure* cases are presented graphically in Figures 5.5-1 and 5.5-2, with annual dose estimates for a single bounding-case year shown as isopleths. In this way, the dose impact for any specific location can be determined by examination and interpolation. In addition, a numerical dose estimate can be pinpointed anywhere at the Site, or within 50 miles of the Site, by utilizing the geographical information system.

In Table 5.5-1, the doses for the *baseline* and *closure* cases were tabulated and compared to radiological protection standards for co-located Site workers, the maximally exposed off-site individual, and the surrounding population. All projected doses from radiological air emissions are well below applicable standards for the worker and members of the public. Thus, the radiological air quality impacts for the *baseline* and *closure* cases are not substantial.

In this section, the details of the *baseline* and *closure* cases, specifically major dose contributors, are discussed. Further descriptions of the actions proposed under the *closure* case are presented in Chapter 3. Supplemental information on source term modeling methodology and itemized results for each of the alternatives are provided in Appendix B "Human Health and Safety."

BASELINE CASE. The greatest contribution to on-site and off-site doses under the *baseline* case is resuspension of contaminated soil in the vicinity of the 903 Pad. That contribution is responsible for more than 80% of the total dose to the co-located worker and 98% of the dose to the maximally exposed off-site individual.

The dose estimates for distances of up to 50 miles from the Site are graphically presented in Figure 5.5-1; the estimated impacts on and near the Site are graphically presented in Figure 5.5-2. Annual dose to the maximally exposed off-site individual under the *baseline* case is well below 1 millirem per year.

CLOSURE CASE. The largest contributors to radiological dose under the *closure* case are from proposed environmental restoration activities and additional point source emissions resulting from the thermal stabilization of plutonium, SNM consolidation and treatment of residues. Although the off-site dose is higher than the *baseline* case, the resulting dose estimate to the maximally exposed individual is still less than 1 millirem per year. The dose estimates for distances of up to 50 miles from the Site and on or near the Site are graphically presented in Figures 5.5-1 and 5.5-2, respectively.

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Figure 5.5-1. Estimated Radiological Dose Impacts within a 50-Mile Radius of the Site for *Baseline* and *Closure*

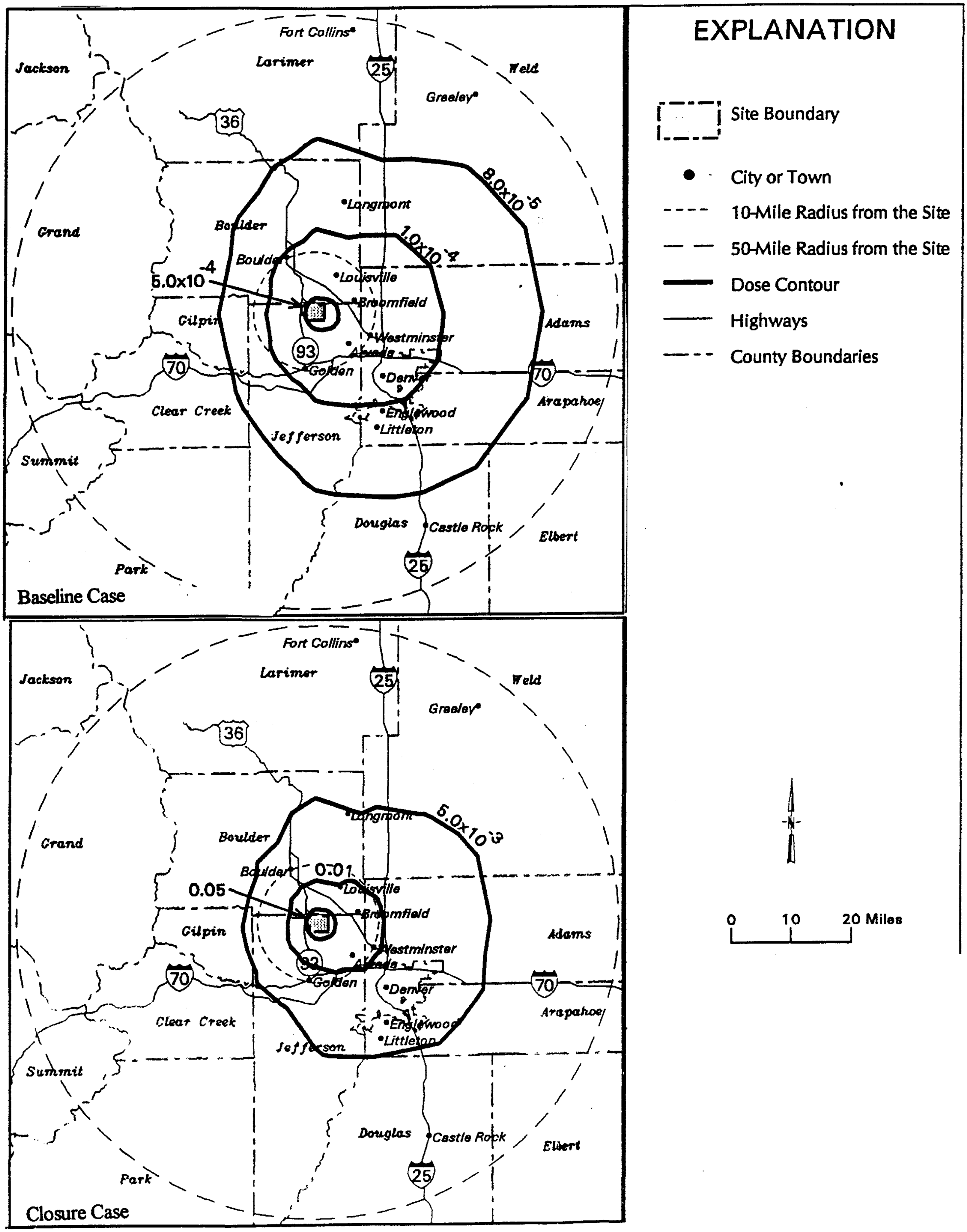
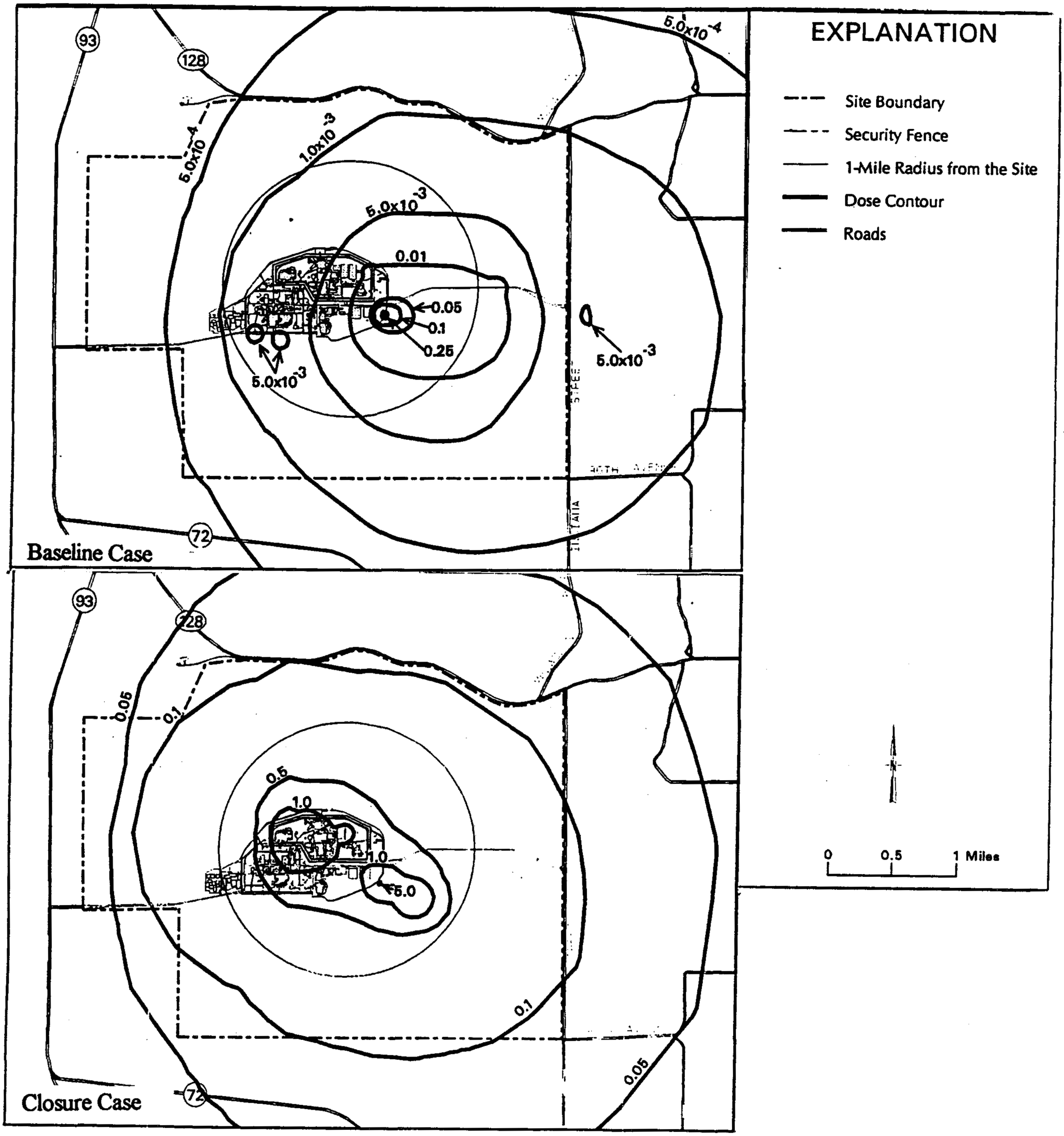


Figure 5.5-2. Estimated Radiological Dose Impacts Near the Site for *Baseline* and *Closure*



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5.5.2 Nonradiological Impacts on Air Quality

This subsection presents the air quality assessment of emissions of nonradiological air pollutants from the *baseline* and *closure* cases. Pollutant concentrations that workers on-site and individuals off-site would be exposed to under each case are quantitatively estimated. These estimates are compared with existing federal and state standards or guidelines designed to protect human health and the environment.

The nonradiological air pollutant sources for this analysis are separated into two major types: point sources and fugitive dust sources. Provided below is a list of the general activities or operations for each source type.

Point Sources

- Steam plant boilers
- Emergency generators
- Laboratories
- Waste management operations
- Wastewater treatment systems

Fugitive Dust Sources

- Excavation or scraping
- Dozer operation
- Vehicle travel on paved and unpaved roads
- Open area wind erosion

Overall, the nonradiological air quality source differences between the *baseline* and *closure* cases result primarily from increased levels of fugitive dust emissions related to environmental restoration activities in the *closure* case. On-site and off-site nonradiological air quality impacts for the *baseline* and the *closure* cases were all found to be below applicable standards and guideline values. Details on air quality impacts for point and fugitive dust sources are presented below.

Methodology

The methodology used for analyzing potential impacts on air quality from routine emission of nonradiological air pollutants is summarized below.

POINT SOURCES. Using procedures outlined in the *baseline* analysis in Section 4.5.3, "Nonradiological Air Quality," both criteria and hazardous air pollutants that are anticipated to be emitted during postulated Site operations associated with the case scenarios were considered in this analysis. Point source emissions were estimated from available Site information. The same reporting thresholds discussed in Section 4.5.3 were used in this analysis to select the pollutants and pollutant sources for analysis. Based on these emission estimates, up to 21 air pollutants were determined to be emitted in quantities greater than the State of Colorado reporting thresholds. The peak short-term and annual emission rates for these pollutants under the *baseline* and *closure* cases are presented in Table 5.5-2. Descriptions of methods used to estimate emissions are provided in Appendix B "Human Health and Safety."

Table 5.5-2. Annual and Hourly Point Source Emissions of Air Pollutants for the *Baseline* and the *Closure* Cases

Pollutants[2]	Annual Average Emissions[1] (tons/year)		Maximum Hourly Emissions[1] (pounds/hour)	
	Baseline Case	*Closure Case*	*Baseline Case*	*Closure Case*
Ammonia[4]	0.71	0.71	0.71	0.71
Benzo(a)pyrene[3,4]	-	5.0×10^{-4}	-	5.0×10^{-4}
Beryllium[4]	3.8×10^{-6}	1.5×10^{-5}	3.8×10^{-6}	1.5×10^{-5}
Carbon Monoxide	41.0	42.0	191	192
Carbon Tetrachloride	0.18	0.31	0.09	0.21
Chlorine	0.11	0.11	0.03	0.03
Chloroform[4]	0.36	0.36	0.36	0.36
Dioctyl Phthalate[4]	0.01	0.01	0.01	0.01
Hydrochloric Acid	0.27	0.52	0.17	0.42
Hydrofluoric Acid	0.10	0.10	0.05	0.05
Hydrogen Sulfide	1.06	1.06	0.26	0.26
Lead	1.7×10^{-12}	1.7×10^{-12}	1.7×10^{-12}	1.7×10^{-12}
Methyl Ethyl Ketone[3,4]	-	0.13	-	0.13
Methylene Chloride	0.47	0.59	0.37	0.50
Nitric Acid	2.11	2.23	1.14	1.26
Nitrogen Dioxide	172	176	861	865
Sulfur Dioxide	11.2	12.2	532	533
Tetrachloroethylene[3,4]	-	0.13	-	0.13
1,1,1-Trichloroethane	1.21	1.33	4.94	5.06

[1]Estimates of hourly emissions of criteria pollutants from steam plant operations were based on burning No. 6 fuel oil and estimates of annual emissions were based on burning natural gas.
[2]PM-10 and TSP emissions from point sources were not used in the dispersion modeling analysis. For *baseline*, Site ambient air quality impacts were based on ambient monitoring data as presented in Section 4.5, "Air".
[3]Pollutant not emitted under *baseline* case but is included in the air quality impact analysis for the *Closure* case.
[4]Maximum hourly emissions (lb./hr) were calculated by adjusting the annual average emissions (tons/yr.) by the number of operating hours per year from multiple paint sources. For example, .1.0 tons/yr. x 2,000 lb./ton divided by 2,000 hrs/yr. (i.e., 40 hrs/week x 50 weeks/yr.) is equal to 1.0 lb./hr.

Following the dispersion modeling procedures discussed in Section 4.5.3, "Nonradiological Air Quality," future pollutant levels of criteria and hazardous pollutants at both on-site and off-site receptor locations under the *baseline* and *closure* cases were estimated using EPA's Industrial Source Complex-2 model (EPA 1992a). This model has been tested and approved by EPA for use in air quality permitting and other applications where predicted ambient air quality concentrations are necessary to fully evaluate possible air quality impacts from sources of air pollutants. The maximum potential impacts of Site emissions for receptors on the foothills located west of the facility, which is considered complex terrain, were determined using EPA's SCREEN2 model in its complex terrain mode.

Pollutant concentrations under these scenarios were evaluated at the same 758 off-site and 782 on-site receptor locations considered for *baseline* conditions. The modeling locations are shown in Figure 4.5-3. A detailed description of the modeling methodology is contained in Appendix B "Human Health and Safety."

FUGITIVE DUST SOURCES. Particulate emissions resulting from non-point sources, such as excavating and material transportation activities, are known as fugitive dust. Activities designed to remediate the Site's contaminated soil would cause atmospheric transport of these fugitive dust emissions. An analysis was conducted to estimate the potential air quality impacts from sources of fugitive dust.

Fugitive dust emissions typically refer to total suspended particulates matter (TSP), but health risks are of concern primarily from particulate matter with aerodynamic diameters less than 10 micrometers (PM-10). Therefore, for this analysis, both TSP and PM-10 emissions were considered. Results of this analysis were compared with appropriate National Ambient Air Quality Standards, State of Colorado air quality standards, and Occupational Safety and Health Administration (OSHA).

Fugitive dust emissions depend on many factors, including the type and duration of construction and remediation activities, soil type, moisture content, surface type (paved, unpaved), movement of transportation vehicles, and meteorological conditions such as wind speed and precipitation. In addition, dust control measures such as watering, covering, stabilization, and street sweeping reduce fugitive dust emissions. Appropriate control factors were incorporated into this analysis to estimate controlled emissions for each dust-producing activity.

PM-10 and TSP emissions for 24-hour and annual periods were estimated from emission factors taken from *Compilation of Air Pollutant Emission Factors, AP42* (EPA 1995a), *Control of Open Fugitive Dust Sources* (Cowhard 1988), and *Uncontrolled Emission Factors for Sand and Gravel Pit Operations* (CDPHE 1995d). The estimated PM-10 and TSP emission rates for the *closure* case activities are presented in Table 5.5-3.

Table 5.5-3. Daily and Annual PM-10 and TSP Emissions Under the *Closure* Case

Fugitive Dust Source	TSP		PM-10	
	lbs/day	tons/year	lbs/day	tons/year
Scraping/ Excavating	18	1.7	10	1.1
Exposed Area Wind Erosion[1]	17	3.2	9	1.7
Dozer/Grader Operations	35	3.5	7	0.7
Unpaved Roads	268	26.7	120	12
Paved Roads	2,758	291.4	530	56.1
Total	**3,096**	**326.5**	**676**	**71.6**

[1]Source category includes emissions from building demolition and soil storage piles.

For the *baseline* case, future on-site and off-site PM-10 and TSP concentrations were assumed to be the same as *baseline* levels presented in Section 4.5.3, "Nonradiological Air Quality," because there are minor environmental restoration or construction activities proposed under this case. Site impacts for PM-10 and TSP for the *baseline* case were obtained from monitoring data for *baseline* conditions. Fugitive dust impacts from remediation and construction activities associated with the *closure* case were added to these *baseline* concentrations to obtain total ambient concentrations for the *closure* case.

The EPA Fugitive Dust Model was used to estimate the impact of PM-10 and TSP emissions of the anticipated construction and remediation activities associated with the *closure* case. Estimated pollutant impacts from future dust generating activities for 24-hour and annual time periods (i.e., time periods corresponding to the applicable standards) were obtained directly from the fugitive dust model output. These values were then added to the *baseline* levels of PM-10 and TSP to obtain total pollutant concentrations. The total pollutant levels were then compared with the appropriate ambient air quality standards. Total 24-hour PM-10 and TSP concentrations at the on-site receptors were converted to 8-hour concentrations using EPA persistence factors that relate 1-hour concentrations to 8- and 24-hour concentrations (EPA 1988). The converted 8-hour values for PM-10 and TSP were then compared with 8-hour OSHA standards to evaluate impacts on co-located workers.

Receptors considered in the dispersion modeling analysis were placed around each of the major emission sources, along the Site boundary, at locations 10 kilometers from the center of the Site in all directions, and in surrounding towns. Details on the emission estimation and modeling methodology are presented in Appendix B "Human Health and Safety."

Comparative Impact Assessment

The concentration of both on-site and off-site nonradiological air quality pollutants for the *baseline* and *closure* cases were found to be below applicable standards and guideline values. Therefore, no substantial adverse nonradiological air quality impacts would result from the *baseline* or *closure* cases.

<u>POINT SOURCES.</u> Results of the on-site modeling analysis for the *baseline* and *closure* cases are presented in Table 5.5-4. On-site concentrations of both criteria and hazardous air pollutants are compared with occupational exposure standards set by OSHA or the American Conference of Government Industrial Hygienists.

As shown in Table 5.5-4, the estimated concentrations of each pollutant are all well below the most restrictive occupational exposure limit with the exception of sulfur dioxide, nitrogen dioxide, and carbon monoxide. The primary sources of these pollutants are diesel-powered emergency generators used to supply back-up power at the Site. The combination of low stack heights, a conservative assumption that all generators were simultaneously operating at maximum capacity, and the proximity of the sources to the receptors resulted in on-site concentrations for these combustion products that approached 50% of the most restrictive occupational exposure limit.

Results of the off-site modeling analysis for criteria and hazardous air pollutants are presented in Table 5.5-5 and Table 5.5-6, respectively. All reported impacts are total concentrations that include impacts from other nearby sources and ambient background concentrations.

Table 5.5-4. Estimated On-Site 8-Hour Concentrations of Criteria and Hazardous Air Pollutants Under the *Baseline* and the *Closure* Cases

Pollutant	Maximum 8-Hour Concentrations[1] (ug/m^3)		Occupational Exposure Standard[2] (ug/m^3)	Percent of Standard	
	Baseline Case	***Closure Case***	(ug/m^3)	***Baseline Case***	***Closure Case***
Criteria Pollutants[3]					
Carbon Monoxide	5,005	5,005	40,000	13	13
Lead	1.7×10^{-10}	1.70×10^{-10}	50	<1	< 1
Nitrogen Dioxide[4]	2,,424	2,426	5,600	43	43
Sulfur Dioxide	2,308	2,308	5,000	46	46
Hazardous Pollutants					
Ammonia[5]	35.7	35.7	17,000	<1	< 1
Benzo(a)pyrene[6]	-	0.03	200	-	< 1
Beryllium	0.0040	0.0070	2.0	<1	< 1
Carbon Tetrachloride	9.3	22.7	12,600	<1	< 1
Chlorine	12.3	12.3	1,500	1	1
Chloroform	5.5	5.5	9,780	<1	< 1
Dioctyl Phthalate	0.7	0.7	5,000	<1	< 1
Hydrochloric Acid	5.1	5.1	7,000	<1	< 1
Hydrofluoric Acid	2.6	2.6	2,500	<1	< 1
Hydrogen Sulfide	98.0	98.0	14,000	1	1
Methyl Ethyl Ketone	-	13.3	590,000	-	< 1
Methylene Chloride	9.5	22.8	1,765,000	<1	< 1
Nitric Acid	33.4	33.4	5,000	1	1
Tetrachloroethylene	-	8.7	689,000	-	< 1
1,1,1-Trichloroethane	3,657	3,657	1,900,000	<1	< 1

[1]The values presented are the highest estimated 8-hour concentrations for on-site receptors.

[2]All occupational exposure values represent OSHA standards unless otherwise specified.

[3]On-site PM-10 and TSP concentrations for baseline and closure cases are presented in Table 5.5-8.

[4]It was assumed that 20% of oxides of nitrogen emissions from stacks are nitrogen dioxide. This is a conservative assumption in that less than 10% of nitrogen oxide emissions from combustion sources are in the form of nitrogen dioxide (Janssen 1988).

[5]Threshold Limit Value established by the American Conference of Government Industrial Hygienists.

[6]Threshold Limit Value established by the American Conference of Government Industrial Hygienists for polycyclic aromatic hydrocarbons was applied to benzo(a)pyrene.

Table 5.5-5. Off-Site Concentrations of Criteria Pollutants Under the *Baseline* and the *Closure* Cases

Pollutant	Average Time	Maximum 8-Hour Concentrations[1] (ug/m^3) *Baseline Case*	Maximum 8-Hour Concentrations[1] (ug/m^3) *Closure Case*	Ambient Std.[2] (ug/m^3)	Percent of Standard *Baseline Case*	Percent of Standard *Closure Case*
Sulfur Dioxide	3-hr 24-hr Annual	448 137 10.8	448 137 10.8	700 365 80	64 38 14	64 38 14
Nitrogen Dioxide[3]	Annual	21.1	21.1	100	21	21
Carbon Monoxide	1-hr 8-hr	14,873 4,301	14,873 4,301	40,000 10,000	37 43	37 43
Lead	Monthly	4.8×10^{-14}	4.8×10^{-14}	1.5	<1	< 1

[1]The values presented are the highest estimated concentrations for off-site receptors at or near the Site boundary, including background levels of these pollutants and impacts from other nearby sources.

[2]The National Ambient Air Quality Standards are shown for all pollutants and averaging periods with the exception of the 3-hour sulfur dioxide and monthly lead standards, which are State of Colorado ambient standards.

[3] It was conservatively assumed that 100% of oxides of nitrogen emissions from stacks are nitrogen dioxide. Although only a small percentage of nitrogen oxide emissions from combustion sources are in the form of nitrogen dioxide, nitrogen oxides convert to nitrogen dioxide in the atmosphere over the time it will take for Site emissions to reach off-site receptors.

Table 5.5-6. Estimated Off-Site Concentrations of Hazardous Pollutants Under *Baseline* and the *Closure* Case

Pollutant	Average Time	Total Concentrations[1] (ug/m^3)		Air Quality Standards[2]	Percent of Standard	
		Baseline Case	*Closure Case*	(ug/m^3)	*Baseline Case*	*Closure Case*
Ammonia	1-hr	7.06	7.06	1,800	< 1	< 1
	8-hr	1.57	1.57	170	< 1	< 1
	24-hr	0.56	0.56	4.73	12	12
	Annual	8.8×10^{-3}	8.8×10^{-3}	4.73	< 1	< 1
Benzo(a)pyrene	1-hr	–	9.0×10^{-3}	0.79	–	1
	8-hr	–	2.0×10^{-3}	6.0×10^{-3}	–	33
	24-hr	–	6.0×10^{-4}	6.0×10^{-3}	–	10
	Annual	–	8.0×10^{-6}	3.0×10^{-4}	–	3
Beryllium	1-hr	4.6×10^{-4}	4.6×10^{-4}	0.05	< 1	< 1
	8-hr	5.7×10^{-5}	8.1×10^{-5}	0.01	< 1	< 1
	24-hr	1.9×10^{-5}	2.5×10^{-5}	1.0×10^{-3}	2	3
	Annual	6.0×10^{-8}	2.4×10^{-7}	4.0×10^{-4}	< 1	< 1
Carbon Tetrachloride	1-hr	9.27	11.37	1,300	< 1	< 1
	8-hr	1.45	1.81	300	< 1	< 1
	24-hr	0.49	0.61	74.4	< 1	< 1
	Annual	0.010	0.012	0.070	15	17
Chlorine	1-hr	8.36	8.36	300	3	3
	8-hr	1.15	1.15	15	8	8
	24-hr	0.38	0.38	3.6	11	11
	Annual	6.3×10^{-3}	6.3×10^{-3}	0.4	2	2
Chloroform	1-hr	3.59	3.59	980	< 1	< 1
	8-hr	0.86	0.86	250	< 1	< 1
	24-hr	0.27	0.27	117.6	< 1	< 1
	Annual	2.9×10^{-3}	2.9×10^{-3}	0.04	7	7
Dioctyl Phthalate	1-hr	0.32	0.32	1,200	< 1	< 1
	8-hr	0.06	0.06	-	-	-
	24-hr	0.02	0.02	-	-	-
	Annual	2.0×10^{-4}	2.0×10^{-4}	12	< 1	< 1
Hydrochloric Acid	1-hr	5.02	5.11	150	3	3
	8-hr	0.69	0.78	75	< 1	1
	24-hr	0.24	0.26	2.03	12	13
	Annual	5.2×10^{-3}	6.2×10^{-3}	2.03	< 1	< 1
Hydrofluoric Acid	1-hr	1.02	1.02	26	4	4
	8-hr	0.14	0.14	26	< 1	< 1
	24-hr	0.06	0.06	0.68	8	8
	Annual	1.3×10^{-3}	1.3×10^{-3}	0.34	< 1	< 1
Hydrogen Sulfide[3]	1-hr	35.29	35.29	142	25	25
	8-hr	4.43	4.43	140	3	3
	24-hr	1.48	1.48	3.79	39	39
	Annual	0.02	0.02	0.9	2	2
Methyl Ethyl Ketone	1-hr	–	2.09	88,500	–	< 1
	8-hr	–	0.36	2,350	–	< 1
	24-hr	–	0.13	360	–	< 1
	Annual	–	1.7×10^{-3}	32.07	–	< 1
Methylene Chloride	1-hr	2.19	4.01	260	< 1	2
	8-hr	0.50	0.70	1,740	< 1	< 1
	24-hr	0.16	0.23	417.6	< 1	< 1
	Annual	4.2×10^{-3}	5.7×10^{-3}	2	< 1	< 1
Nitric Acid	1-hr	22.06	22.06	500	4	4
	8-hr	3.07	3.09	100	3	3
	24-hr	1.13	1.14	50	2	2
	Annual	0.03	0.03	0.12	24	24

Table 5.5-6. Continued
Estimated Off-Site Concentrations of Hazardous Pollutants Under *Baseline* and the draft Site Closure Plan

		Total Concentrations[1] (ug/m^3)		Occupational Exposure Standards[2]	Percent of Standard	
Pollutant	**Average Time**	***Baseline***	**draft Site Closure Plan**	**(ug/m^3)**	***Baseline***	**draft Site Closure Plan**
Tetrachloroethylene	1-hr 8-hr 24-hr Annual	– – – –	2.46 0.53 0.16 2.1 x 10^{-3}	11,000 1,700 770 0.01	– – – –	< 1 < 1 < 1 21
1,1,1,-Trichloroethane	1-hr 8-hr 24-hr Annual	414 52.1 17.4 0.02	414 52.1 17.4 0.02	190,000 38,000 1,040 1,000	< 1 < 1 2 < 1	< 1 < 1 2 < 1

[1]The values presented are the highest concentrations estimated for off-site receptors around the Site, including impacts from other nearby sources.
[2]Recommended values are the air quality guidelines, values, or standards for hazardous air pollutants developed by different states, as discussed in Appendix B "Human Health and Safety."
[3]The State of Colorado ambient standard for hydrogen sulfide was used as a recommended value.

The highest off-site impacts are found at receptors located along or near the Site boundary. The estimated total off-site concentrations of criteria pollutants under the *closure* case were all below National Ambient Air Quality Standards and State of Colorado air quality standards. The estimated total off-site concentrations of hazardous air pollutants from Site activities are compared with recommended guideline values specifically developed for this analysis using standards and guidelines from 12 different states, as discussed in Section 4.5.3, "Nonradiological Air Quality." Maximum off-site concentrations of hazardous air pollutants considered were found to be below the recommended values.

Complex terrain modeling was conducted to determine concentrations of pollutants at elevated receptors west of the Site under the *closure* case. Pollutant concentrations were below all standards and recommended values. Details of this analysis and analytical results are presented in Appendix B "Human Health and Safety."

FUGITIVE DUST SOURCES. Predicted on-site 8-hour concentrations were compared with the appropriate OSHA standards for PM-10 and TSP. The ambient monitoring data for the *baseline* and modeling results for the *closure* cases are presented in Table 5.5-7.

Table 5.5-7. 8-Hour PM-10 and TSP Concentrations at On-Site Receptors

	Maximum 8-Hr Concentration[1] (ug/m^3)		Occupational Exposure Standards	Percent of the Standard	
Pollutant	***Baseline Case***	***Closure Case***	**(ug/m^3)**	***Baseline Case***	***Closure Case***
PM-10	90.8	284.7	5,000	2	6
TSP	157./5	987.4	15,000	1	7

[1]Developed from monitored and modeled 24-hour values using persistence factor of 1.75, as described in Section 5.5.2, "Nonradiological Impacts on Air Quality."

The on-site PM-10 and TSP concentrations are below applicable occupational health standards. Impacts for the *closure* case would be much higher than the *baseline* case because of environmental restoration activities such as excavation, equipment operation, and transport of material on unpaved roads.

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Predicted off-site 24-hour and annual concentrations were compared with National Ambient Air Quality Standards for PM-10 and State of Colorado standards for TSP. The results presented in Table 5.5-8 show that the total predicted concentrations of both PM-10 and TSP are below appropriate standards. All maximum concentrations for TSP and PM-10 are found at receptors located on or near the Site boundary.

Table 5.5-8. 24-Hour and Annual PM-10 and TSP Concentrations at Off-Site Receptors

Pollutant	Avg. Time	Total Concentration[1] (ug/m^3)		Ambient Standard[2]	Percent of the Standard	
		Baseline Case[3]	*Closure* Case	(ug/m^3)	*Baseline* Case	*Closure* Case
PM-10	24-hr Annual	32.0 14.0	37.5 22.4	150* 50	21 28	25 45
TSP	24-hr Annual	73.0 31.0	86.3 41.8	260 75	28 41	33 56

[1]Total concentrations include *baseline* plus impacts from environmental restoration activities for the *closure* case.
[2]The National Ambient Air Quality Standard is shown for PM-10, and the State of Colorado standard is shown for TSP. The 24-hour TSP and PM-10 standards are compared to the second highest monitored or modeled concentration per requirements in 40 CFR 50.6.
[3]The off-site fugitive dust impacts for the *baseline* are assumed to be the second highest 24-hour and highest annual monitored concentrations recorded by the Colorado Department of Public Health and Environment (CDPHE) ambient TSP and PM-10 monitors located at the eastern boundary of the Site.

FUGITIVE ORGANIC AIR EMISSION SOURCES. The potential exists for organic air emissions during the excavation of certain source areas for environmental restoration under the *closure* case. Due to the short-term nature of these excavations, limited soil concentration data and uncertainty associated with estimating organic emissions during excavation, air emissions from these activities were not modeled. Potential impacts on workers and the public from these activities are addressed in a Proposed Action Memorandum for each source area as part of the RFCA process. In addition, project-specific risk assessments are performed to identify and lessen the human health risks to the on-site worker and members of the public. Ambient modeling is also performed during the actual excavation to ensure air emissions remain within acceptable levels per the requirements of the project-specific Health and Safety Plan.

Summary of Nonradiological Air Quality

Air quality conditions resulting from both on-site and off-site nonradiological air quality emissions from Site activities under the *baseline* and *closure* cases were estimated using very conservative assumptions for maximum emission rates and source locations with respect to the Site boundary. All estimated levels of criteria and hazardous pollutants were below applicable federal and state standards and recommended values. Therefore, the nonradiological air quality impacts for the *baseline* and *closure* cases are not substantial. Potential health risks associated with emissions from the Site under future activities are presented in Section 5.8, "Impacts on Human Health and Safety."

The primary differences between the *baseline* and *closure* cases for predicted on-site and off-site nonradiological air emission concentrations are the result of fugitive dust emissions from environmental restoration and building demolition operations.

5.6 Impacts on Traffic and Transportation

This section presents evaluations of impacts that would result from on-site and off-site traffic and transportation activities under the *baseline* and *closure* cases at the Site. The section is organized as follows:

- Local traffic impacts
- Routine transportation impacts (on-site)
- Routine transportation impacts (off-site)
- Accident impacts (on-site)
- Accident impacts (off-site)

Criteria for evaluating the significance of impacts vary according to the types of impacts and are described in each section. More detailed information on traffic and transportation impacts can be found in Appendix A, "Traffic and Transportation." This assessment for the *closure* case is based on the draft Site Closure Plan reference case 2 funding profile.

5.6.1 Local Traffic Impacts

Local traffic impacts are defined as impacts of Site-related personal vehicles and commercial trucks on traffic volumes on local highways near the Site. Site workers use personal vehicles to commute to and from the Site (there is no public transport that serves the Site, and a previously available van-pool system is no longer in operation). Commercial vehicles bring materials and supplies to the Site and transport materials and waste from the Site to other locations. Commercial truck traffic includes removal of radioactive and hazardous waste from the Site, transport of clean fill materials to the Site (e.g., to replace excavated soil), transport of materials for day-to-day Site operations (e.g., food, building materials, office supplies), and transport of materials associated with economic conversion activities. As local traffic levels vary, traffic on Site roads will also vary. Thus fluctuation in traffic levels discussed below reflect both local and on-site traffic conditions.

The average daily additions to traffic from Site-related vehicles for the *baseline and closure* cases are shown in Table 5.6-1. The baseline case reflects 1994 levels of traffic. Due to the recent change to an integrating management contractor with first-tier and numerous sub-tier subcontractors, the current trend is toward a reduction in personal vehicle traffic and an increase in commercial truck traffic. For the *closure* case, the table shows the daily number of Site-related commuter vehicles and commercial trucks using public highways: 1) averaged over a high activity period (e.g., 10 to 15 years) when most buildings will be DD&D'd, and 2) averaged over a theoretical single year projected to have the highest traffic volume.

Table 5.6-1. Average Daily Traffic Volume to and from the Site for Both Cases

	Baseline Case	*Closure Case*	
	Average	**Average Year**	**Maximum Year**
Personal Vehicle	6,539	4,332	6,460
Commercial Truck	13	99	112

Congestion is the primary impact of concern with respect to traffic. A quantitative evaluation of projected traffic patterns in the vicinity of the Site was not included in the scope of CID, therefore, assessment of traffic impacts is general and qualitative. Despite varying traffic levels between the *baseline and closure* cases, congestion levels would not be expected to increase substantially. Personal vehicle usage decline due to the reduced staffing levels over the *closure* case timeframe. Cargo-related traffic would be scheduled to avoid peak traffic periods (i.e., shift changes) to avert potential impacts. For the *closure* case, truck traffic would be 8 to 10 times higher than during the *baseline* case due to the very large volumes of waste being transported over-the-road for off-site disposal. This increase in truck traffic volume is high enough to be noticeable on the highways in the immediate vicinity of the Site but would be scheduled such that it would not add to overall local road congestion. Beyond the high activity timeframe, Site-related traffic would drop substantially under the *closure* case because ongoing operations and staffing levels would be much reduced.

5.6.2 Routine Transportation Impacts

All vehicular traffic causes some human health impacts, regardless of the purpose of the trip or the content of the cargo. Vehicle-related impacts normally incidental to transportation include air pollution caused by tailpipe emissions, tire and brake wear, and suspension of fugitive dust and other particulate material, which, when inhaled, may affect human health. Cargo-related impacts normally incidental to transportation include exposures from the release of minute amounts of hazardous or toxic materials in the form of gases from packaging and the emission of small quantities of radiation from shipping packages (without actual leakage from the packages).

With regard to the Site, vehicle-related activities were analyzed for transport of materials and waste and use of government vehicles. Cargo-related impacts were also analyzed for these activities with the exception of sanitary waste transport and government vehicle use.

Vehicle-related impacts are reported in terms of the number of individuals who may die from cancers developed from inhaling pollutants, fugitive dust, and other particulate material. Because the cancers may take many years to develop, they are called latent cancers. Potential impacts resulting from vehicle-related activities at the Site are reported as excess latent cancer fatalities.

Cargo-related impacts are reported in terms of radiation dose, which is measured in rem for individuals and person-rem for collective groups. By applying the appropriate health effects conversion factors to these radiation doses, the doses can be expressed in terms of excess latent cancer fatalities. Cargo-related impacts can also involve the release of minute amounts of hazardous or toxic materials in the form of gases from packaging. However, the requirements for material packaging make the likelihood of such hazardous or chemical releases small enough that they are not analyzed further.

On-Site Transportation

Impacts on human health from routine on-site transportation for the *baseline and closure* cases are presented in Table 5.6-2. Impacts were summed over all populations (transportation workers, co-located workers, and the public) for vehicle-related impacts. Impacts are presented separately for transportation workers and co-located workers (assumed to be located 10 feet from the roadway) for cargo-related impacts. All risks are presented as annual averages and cumulative totals for the high activity period of the *closure* case.

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Table 5.6-2. Excess Latent Cancer Fatalities (LCF) from Routine On-Site Transportation

Source of Impact	*Baseline Case* Risk (LCF/yr)	*Closure Case* Annual Risk (LCF/yr)	*Closure Case* Risks from High Activity Period (LCF/10-Years)
Vehicle-Related	2.9×10^{-1}	1.8×10^{-1}	1.8
Cargo-Related - Transportation Workers	2.2×10^{-3}	3.4×10^{-3}	3.4×10^{-2}
Cargo-Related - Co-Located Workers	4.0×10^{-7}	6.1×10^{-7}	6.1×10^{-6}
Total Incident-Free Impacts	$\mathbf{2.9 \times 10^{-1}}$	$\mathbf{1.8 \times 10^{-1}}$	**1.8**

The *closure* case has less risk with regard to routine on-site transportation impacts, which is attributable primarily to the substantial reduction in workforce during the *baseline* case and *closure* case high activity timeframe (e.g., 10 to 15 years). The risk from incident-free routine transportation is dominated by vehicle-related causes for both the *baseline and closure* case. It should also be noted that vehicle-related impacts occur from all vehicle usage such that Site workers would be exposed to similar or higher pollutant levels if they were employed elsewhere. Cargo-related radiation exposures represent a very small fraction of routine on-site transportation impacts and are not considered to be substantial. Additional details concerning routine on-site transportation impacts (such as material characterization, number of trips, and methodology) are presented in Appendix A, "Traffic and Transportation."

Off-Site Transportation

This section assesses impacts on human health from routine off-site transportation activities. The types of vehicle-related impacts discussed above for on-site transportation (vehicle- and cargo-related) also apply to off-site transportation and are considered below.

Existing waste inventories and waste generated from residue treatment, routine operations, environmental restoration, and DD&D would be transported off-site. The *closure* case estimates that off-site transportation volumes are based on the Ten Year Plan reference case 2 funding profile. Table 5.6-3 presents the volume and number of off-site shipments for each waste type by *baseline* and *closure* case.

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Table 5.6-3. Off-Site Transportation Activities

Material	Source	Destination	*Baseline Case*		*Closure Case*			
			Trips/yr	Annual Volume (yd^3)	Trips/yr	Annual Volume (yd^3)	10-yr Trips	10-yr Volume (yd^3)
Low-Level Waste	Operations	Nevada Test Site	57	927	81	1,187	807	11,871
	Operations	Hanford	0	0	0	0	0	0
	Environmental Restoration	Nevada Test Site	0	0	2,404	50,000	24,038	500,000
Low-Level Mixed Waste	Operations	Nevada Test Site	0	0	186	2,731	1,857	27,307
	Operations	Envirocare	36	754	36	754	364	7,537
	Environmental Restoration	Envirocare	0	0	5,510	81,000	55,102	810,000
TRU and TRU-mixed	Operations	Waste Isolation Pilot Plant	0	0	42	479	416	4,785
Residues	Operations	Waste Isolation Pilot Plant	0	0	420	4,790	4,160	47,850
RCRA (hazardous)	Operations	Waste Broker	7	48	7	48	70	483
Sanitary Waste	Operations	Off-site	0	0	1,231	18,106	12,312	181,057
TSCA	Operations	Waste Broker	1	2	1	2	10	20
TSCA (radioactive)	Operations	Hanford	1	4	1	4	10	40
Environmental Restoration Fill	Local Off-Site	On-site	0	0	11,259	144,218	112,585	1,442,175
SNM	Operations	Other DOE site (analysis assumes Savannah River)	1	classified	6	classified	63	9.8 metric tons

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Table 5.6-4 presents the mileage estimated for transportation activities not involving waste over the 10-year timeframe of the *baseline* and *closure* case.

Table 5.6-4. Estimated Mileage for On-Site Transportation Activities for the *Baseline* and *Closure* Cases

Transportation Type	*Baseline Case*		*Closure Case*			
	Trips/yr	Miles/yr	Trips/yr	Miles/yr	High Activity Trips	High Activity Period Miles
Commuters[1]	3.4 million	78 million	2.3 million	52 million	23 million	517 million
Incoming Environmental Restoration Shipments	0	0	7,914	131,000	79,140	1.3×10^6
Economic Conversion Receipts	0	0	110	2,370	1,097	23,700
Local Non-Hazardous Shipments[2]	N/A	49,280	N/A	7,052	N/A	70,520

[1]Commuter trip and mileage numbers have been rounded off.
[2]In equivalent miles.

Routine vehicle-related impacts are not specific to any one group; that is, they do not impact workers directly involved in transportation activities any more than the general public. Vehicle-related impacts from tailpipe emissions, fugitive dust, and tire/brake particles were calculated by multiplying the total number of miles traveled by a "unit risk factor" for the type of vehicle involved. This calculation resulted in an estimate of the excess latent cancer fatalities per vehicle mile traveled. The unit risk factor used for commuter vehicles was 1.6×10^{-8} excess latent cancer fatalities per mile (EG&G 1992e). The unit risk factor for commercial trucks was 1.6×10^{-7} excess latent cancer fatalities per mile (Rao 1982). Improvements in automotive engines, fuel mixtures, and transportation speeds since the unit risk factors were determined would tend to lead to an overestimate of current risks. To further ensure conservative estimates of risk, it was assumed that all miles traveled were urban miles (which involve a higher risk factor).

For routine cargo-related impacts associated with transport of radioactive materials, the HIGHWAY model was used to determine the most likely truck travel routes used to reach a particular destination (Johnson 1993). Restrictions on truck travel over certain roads were taken into account in determining the routes. The model calculated the number of miles traveled over rural, suburban, and urban roads based on updated 1990 census data. The results were then input to a model called RADTRAN 4 (Neuhauser 1992) to calculate the cargo-related dose (in millirem) and risk (in excess latent cancer fatalities) per mile traveled.

Vehicle-related and cargo-related impacts resulting from routine off-site transportation activities are presented in Table 5.6-5. Impacts are reported for annual averages and the high activity timeframe of the *baseline* and *closure* case.

Table 5.6-5. Total Excess Latent Cancer Fatalities Resulting from Routine Off-Site Transportation for All Populations

Source of Impact	*Baseline Case* Risk (LCF/yr)	*Closure Case* Annual Risk (LCF/yr)	*Closure Case* Risks from High Activity Period (LCF/10-Years)
Vehicle-related (Commuter)	1	0.8	8
Vehicle-related (Truck)	1×10^{-3}	4×10^{-2}	0.4
Cargo-related - Worker	7×10^{-4}	5×10^{-3}	5×10^{-2}
Cargo-related - Public	3×10^{-8}	2×10^{-7}	2×10^{-6}
Total incident-free off-site transportation impacts	**1**	**0.9**	**9**

As the table indicates, commuter travel to and from the Site is the largest contributor to excess latent cancer fatalities resulting from routine transportation activities and that vehicle-related pollution is a significant cause of human health risk in urban settings. Other off-site transportation of waste, SNM, and other materials have risks that are one to two orders of magnitude less than that from commuter travel. It should be noted that if these individuals were not working at the Site, they would probably be commuting to work somewhere else contributing the same level of risk. Commuter miles traveled are based on information in the *Site-Wide Evaluation of Transportation Risks for the Rocky Flats Plant* (EG&G 1992e), scaled by the estimated number of employees per the draft Site Closure Plan reference case 2, averaged over a 10-year period. The lower number of fatalities for the *closure* case is due to a decreasing workforce over the high activity period.

As can also be seen from Table 5.6-5 the risk from routine radiation exposures from incident-free off-site transportation is several orders of magnitude less than the risk from commuter travel. Also, the risk to the public from transportation radiation exposures is much less than that to the transportation workers.

5.6.3 Accident Impacts

Potential accidents are of concern with all transportation. The following subsections describe estimated impacts for on-site and off-site transportation.

On-Site Accidents

Several accident scenarios could occur during the on-site transfer of radioactive material that would have severe consequences to workers at the Site and to the general public within 50 miles of the Site. Though highly unlikely due to the extensive safety precautions taken during transport of such materials, these scenarios would typically involve collision and possibly fires involving the transfer vehicle. Such an accident could conceivably be severe enough to result in the breach of packages within the vehicle and the subsequent release of radioactive material.

This section describes the estimated human health impacts resulting from a worst-case accident during the transfer of radioactive material on-site. The on-site accident that was postulated to cause the greatest impacts on human health involved the release of 82.5 grams of weapons-grade plutonium in the form of a stabilized oxide as a result of a fire during an on-site truck transport (DOE 1995l). This accident could occur for the *baseline* and *closure* cases, and risk is only differentiated between the *baseline* and *closure* cases according to the frequency of occurrence.

Other on-site transportation accidents involving SNM, residues, TRU waste, and low-level wastes were evaluated but were determined to represent lower risks. For example, an accident

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involving plutonium oxide in unstabilized (pyrophoric) form would seem likely to result in more severe impacts than an accident involving stabilized oxide; however, because restrictions limit the amount of unstabilized oxide that can be transported at any one time, resultant impacts were calculated to be less severe. (Restrictions also exist on the amount of stabilized oxide that can be transported at any one time, but the limits are higher). The risks from on-site transportation activities are currently being re-evaluated for the draft Site Safety Analysis Report.

To ensure that estimates of impacts were conservative and unlikely to be exceeded, it was assumed that the truck involved in the accident was loaded to its maximum capacity. The accident was assumed to be of sufficient severity to rupture the fuel tank of the truck and produce a fire which eventually involved the entire vehicle. Up to 50% of the packages in the vehicle were assumed to be destroyed with a resultant loss of contents (Halliburton 1991). Such an accident would result in the environmental release of 82.5 grams of plutonium. Additional information concerning accident scenario development is presented in Appendix A, "Traffic and Transportation."

To calculate the risk of latent cancer fatalities from a postulated accident, the estimated dose to a specific receptor must be multiplied by the appropriate health effects conversion factor, then this result must be multiplied by the estimated frequency of occurrence. Each of these steps is described below.

ESTIMATED DOSES TO SPECIFIC RECEPTORS. The radiological impacts of potential accidents during on-site transportation activities were assessed using a model called MACCS. Doses were determined for the following receptors: 1) individual dose to the maximally exposed co-located worker at the Site, 2) individual dose to the maximally exposed individual member of the public; and 3) collective dose to the general public within 50 miles of the Site. Doses were not assessed for the transport driver(s) involved in the accident, since the accident was assumed to be severe enough to be fatal. Internal and external doses were summed to calculate dose to the person as a whole (total effective dose equivalent) over 50 years. For more information on calculating radiological dose, see Section 4.8.1, "Radiological Health and Safety–Worker."

The calculated results are presented as 1) median (50th percentile) values and 2) 95th percentile values (the value corresponding to "worst-case" meteorology, expected to be exceeded only 5% of the time in a given year).

Table 5.6-6 presents doses (in rem) to the maximally exposed co-located worker at the Site, the maximally exposed individual member of the general public, and excess latent cancer fatalities for the general public within a 50-mile radius of the Site.

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Table 5.6-6. Bounding On-Site Transportation Accident Involving Plutonium

Scenario	Consequences		*Baseline Case*		*Closure Case*	
	Median	95^{th}	Frequency (/yr)	Risk (consequences per yr)	Frequency (/yr)	Risk (consequences per yr)
Co-Located Worker Dose (rem CEDE)	7.0×10^{-1}	$3.0 \times 10^{+2}$	4×10^{-7}	2.8×10^{-7}	1×10^{-6}	7.0×10^{-7}
Maximally Exposed Off-site Individual Dose (rem CEDE)	$2.0 \times 10^{+0}$	$8.5 \times 10^{+0}$	4×10^{-7}	8.0×10^{-7}	1×10^{-6}	2.0×10^{-6}
Population Latent Cancer Fatalities (LCF)	$1.2 \times 10^{+0}$	$1.4 \times 10^{+1}$	4×10^{-7}	4.8×10^{-7}	1×10^{-6}	1.2×10^{-6}

DOSE TO THE CO-LOCATED WORKER. The co-located worker located at a point 100 meters from the plutonium transport accident would receive a dose of 0.7 rem under median conditions. The lofting of the plume due to the fire results in less dose to the co-located worker than if the release were at ground level.

DOSE TO THE MAXIMALLY EXPOSED INDIVIDUAL. The maximally exposed off-site individual would receive a dose of 2 rem under median conditions. This dose is at approximately 4 miles from the Site due to the lofting of the fire plume.

For purposes of comparison, the dose standard recommended by the International Commission on Radiological Protection and adopted by DOE for total dose resulting from all pathways is 100 millirem (0.1 rem) per year to any member of the general public. The annual limit for whole body exposure to a DOE radiation worker is 5 rem (10 CFR 835); however, DOE has set a lower annual limit of 2 rem, and the Site has set an even lower limit of 750 millirem (0.75 rem). The dose to the maximally exposed individual under this hypothetical accident scenario would actually be closer to the annual dose limits applied to DOE radiation workers. While these limits are applicable to DOE radiation workers and not meant for members of the public, they may be useful for purposes of comparison.

DOSE TO THE GENERAL PUBLIC. Approximately 1 excess latent cancer fatalities would be predicted to occur within a 50-mile radius of the Site as a result of a worst-case transport accident on-site.

ACCIDENT FREQUENCIES. Once doses have been calculated, the frequency of occurrence of a particular accident must be taken into account to provide a realistic estimate of the actual risk to potential receptors. The doses calculated for the plutonium transport accident described above are predicted if a release occurs. However, such an occurrence is highly unlikely. No such accident has ever occurred, and stringent safety precautions are taken during on-site transport of plutonium materials to ensure that such an accident does not occur (including clearing affected roads of all traffic, providing a security escort for the transport vehicle, and restricting speeds to under 10 miles per hour).

If a plutonium transport accident were to occur, the health effects would be the same for the *baseline* and *closure* cases. However, the frequency of occurrence for such an accident may vary somewhat for the *baseline* and *closure* cases, depending on the amount of SNM transport expected to take place. For example, under the *baseline* case, SNM was stored in existing buildings, so on-site transport of SNM would be minimal. Thus the probability of a plutonium transport accident occurring under the *baseline* case would be lower than for the *closure* case, in which SNM would be consolidated in Building 371 and then later in a new SNM storage vault. Consolidation would require considerably more SNM shipment activity. This resulted in estimated accident frequencies for the postulated plutonium transport accident of 4×10^{-7} per year for the *baseline* case and 1×10^{-6} per year for the *closure* case. See Appendix A, "Traffic and Transportation" for a further discussion of accident frequencies.

ON-SITE ACCIDENT RISKS. Based on the consequences presented in Table 5.6-6 and the accident frequencies, risk to the co-located worker, maximally exposed off-site individual, and population is presented in Table 5.6-6. The risk for the *closure* case is approximately three times higher than for the *baseline* case due to the increased frequency of on-site transportation activities.

Off-Site Accidents

This section describes vehicle-related and cargo-related accidents off-site. Vehicle-related accidents include commuter accidents involving Site workers and commercial truck accidents unrelated to the cargo being carried. Cargo-related accidents involve releases of hazardous, toxic, or radioactive materials resulting from rupture of containers due to an accident.

VEHICLE-RELATED OFF-SITE ACCIDENTS. From a statistical standpoint, a certain number of vehicular accidents can be expected to occur based on the expected amount of commuter and truck traffic to and from a particular location. Traffic to and from the Site includes commuters, shipments of waste off-site for disposal, removal of non-hazardous materials from the Site, and shipment of non-regulated materials to the Site (e.g., equipment and office supplies). Table 5.6-7 presents the number of fatalities estimated to occur for the *baseline* case and annual averages for the high activity period during the *closure* case.

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Table 5.6-7. Estimated Traffic Fatalities from Off-Site Traffic for *Baseline* and *Closure Cases*

Source	*Baseline Case* Risks (fatalities/ yr)	*Closure Case* Annual Risks (fatalities/ yr)	*Closure Case* Risks over High Activity Period (fatalities/ 10-yrs)
Commuting	1.6	1	10
Local Incoming			
Environmental Restoration	0	0.001	0.01
Economic Conversion	0	0.01	0.1
Denver Metro Area (Non-Hazardous)	0	0	0
Local Outgoing			
RCRA	0	0	0
TSCA	0	0	0
Denver Metro Area (Non-Hazardous)	0	0	0
Sanitary	0	0.0001	0.001
Radioactive			
Low-level to NTS (Ops.)	0	0.007	0.07
Low-level to NTS (Env. Rest.)	0	0.2	2
Low-level mixed to NTS (Ops.)	0	0.02	0.2
Low-level mixed to Envirocare (Ops.)	0	0.002	0.02
Low-level mixed to Envirocare (Env. Rest.)	0	0.4	4
TSCA to Hanford (Ops.)	0	0.0001	0.001
TRU and TRU-mixed to WIPP	0	0.004	0.04
Residues as TRU to WIPP	0	0.04	0.4
SNM to Savannah River	0	0	0
Total Off-Site Traffic Fatalities Impacts	**1.6**	**1.7**	**17**

Note: For very low mileage, a zero value for Accident Fatalities is shown since no traffic fatalities are statistically expected because the calculated value is much less than 1.0.

Additional details such as average trip distance, number of trips, and total miles traveled are presented in Appendix A, "Traffic and Transportation," based on the draft Site Closure Plan reference case 2. For both cases, the largest contributor to vehicular accidents is commuter traffic to and from the Site. The lower number of fatalities under the *closure* case can be attributed primarily to the substantial workforce reduction that would occur during the *baseline* case and *closure* case high activity timeframe. The slightly higher number of fatalities for the *closure* case can be attributed primarily to the greater number of trucks on the highway moving waste and clean fill materials to and from the Site. By way of comparison, in 1995 alone, there were 645 traffic fatalities in the State of Colorado (CDOT 1996), compared to the less than 2 fatalities per year for the *baseline* and *closure* cases.

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CARGO-RELATED OFF-SITE ACCIDENTS. Cargo-related impacts were also calculated under off-site transportation accident conditions. The analysis included radioactive material potentially released from shipments of low-level, low-level mixed, and TRU and TRU-mixed waste (including residues that will be processed as TRU/TRU-mixed waste) The impacts of the release of carcinogenic and toxic chemicals were calculated for low-level mixed waste, radioactively contaminated Toxic Substances Control Act (TSCA) waste, and TRU-mixed waste.

Table 5.6-8 shows the cargo-related carcinogenic impacts from an off-site accident for the *baseline* and *closure* cases. Radiological impacts are expressed in terms of risk of excess latent cancer fatalities from the estimated dose to the general public. Chemical impacts are expressed in terms of risk of cancer incidence to a member of the public located 100 meters from the transport corridor.

Table 5.6-8. Cargo-Related Carcinogenic Impacts to the General Public from an Off-Site Accident

	Baseline Case Risks (LCF/yr)		*Closure Case* Annual Risks (LCF/yr)		*Closure Case* Risks from High Activity Period (LCF/10-Years)	
Source	**Rad**[1]	**Chem**[2]	**Rad**	**Chem**	**Rad**	**Chem**
Low-level to NTS (Ops.)	8×10^{-4}	–	1×10^{-3}	–	1×10^{-2}	–
Low-level to NTS (Env. Rest.)	0	–	4×10^{-2}	–	4×10^{-1}	–
Low-level mixed to NTS (Ops.)	0	0	3×10^{-3}	4×10^{-10}	3×10^{-2}	4×10^{-9}
Low-level mixed to Envirocare (Ops.)	6×10^{-4}	7×10^{-11}	6×10^{-4}	7×10^{-11}	6×10^{-3}	7×10^{-10}
Low-level mixed to Envirocare (Env. Rest.)	0	0	9×10^{-2}	1×10^{-8}	9×10^{-1}	1×10^{-7}
TSCA to Hanford (Ops.)	2×10^{-5}	2×10^{-16}	2×10^{-5}	2×10^{-16}	2×10^{-4}	2×10^{-15}
TRU/TRU-mixed to WIPP	0	0	7×10^{-5}	2×10^{-12}	7×10^{-4}	2×10^{-11}
TRU residues to WIPP	0	0	7×10^{-4}	2×10^{-11}	7×10^{-3}	2×10^{-10}
Accident Risk from Cargo Accidents	$\mathbf{2 \times 10^{-3}}$	$\mathbf{7 \times 10^{-11}}$	$\mathbf{1 \times 10^{-1}}$	$\mathbf{1 \times 10^{-8}}$	**1**	$\mathbf{1 \times 10^{-7}}$

[1]Radiological impacts are expressed in terms of risk of excess latent cancer fatalities for the off-site public.
[2]Chemical impacts are expressed in terms of risk of latent cancer incidence to an individual 100 meters from the transport corridor.

Chemical and radiological health risks are highest for the *closure* case due to the increased number of shipments of low-level and low-level mixed waste to the Nevada Test Site and Envirocare. This risk of fatalities from cargo-related impacts is not considered significant because it is less than the risk from commuter traffic fatalities (as shown on Table 5.6-7) by at least a factor of 10. Additionally, fatalities from cargo-related effects would be spread over the much larger population along all transportation routes as opposed to just the local population, which would experience commuting fatalities.

More immediate impacts can occur from exposure to noncarcinogenic toxic chemicals. The probabilistic hazard index for noncarcinogenic chemical risks are estimated to be much less than

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1.0 (i.e., 8×10^{-8} for the *baseline* case and 1×10^{-5} for the *closure* case), indicating a negligible noncarcinogenic risk.

With respect to transportation of SNM off-site, SNM has been transported in safe-secure trailers since 1975. In that time, these vehicles have transported materials over 75 million miles without any accidents that resulted in a release of radioactive materials. For this reason and in accord with the *Storage and Disposition of Weapons-Usable Fissile Materials Programmatic Environmental Impact Statement* (DOE 1996b), no radiological accident impacts have been attributed to off-site transportation of SNM.

METHODOLOGY. As with routine off-site transportation impacts, RADTRAN 4 was used to model radiological accident impacts. Chemical risks were calculated using unit risk factors as developed in the *Site-Wide Evaluation of Transportation Risks for the Rocky Flats Plant* (EG&G 1992e). A detailed description of both methodologies is presented in Appendix A, "Traffic and Transportation."

5.7 Impacts on Utilities and Energy

Utility usage at the Site includes water, steam, natural gas, fuel oil, electricity, and nitrogen gas. The current usage and supply system for each of these utilities is described in Section 4.7, "Utilities and Energy." Table 5.7-1 presents a qualitative comparison of the impacts on utility usage of the *closure* case to the *baseline* case of December 1996.

Table 5.7-1. Impacts on Utilities and Energy by *Baseline Case and Closure Case*

Utility	*Baseline Case*	*Closure Case*
Water	Approximately 130 million gallons per year.	**Decrease** due to reduced work force levels, but offset somewhat by increased facility DD&D. Large decrease after facility DD&D activities are completed and Site activities are greatly reduced.
Steam	Approximately 425 million pounds per year.	**Decrease** due to eliminated steam needs following facility DD&D.
Natural Gas and Other Fuels (fuel oil, diesel fuel, gasoline)	Approximately 640 million cubic feet per year.	**Decrease** as buildings are decommissioned.
Electricity	Approximately 12.5 gigawatt-hours per month.	**Decrease** as buildings are decommissioned.
Nitrogen Gas	Approximately 125,000 cubic feet per hour.	**Decrease** due to accelerated stabilization of SNM.

Utility usage at the Site is primarily related to facility activities and only secondarily to workers and processes. For example, electricity usage on a weekend day is only 10% to 15% less than electricity usage on a weekday. As a result, activities aimed at reducing or eliminating building usage (such as facility DD&D and consolidation of waste or SNM into a single building) have a proportionately larger effect on overall utility requirements than work force levels or treatment processes. Under the *closure* case a limited number of buildings would be left after building DD&D. Due to the decreased water requirement after DD&D it is likely small scale water treatment units would be utilized versus keeping the water treatment plant. Once building DD&D is complete in 2012 all utility usage will be dramatically reduced and therefore impacts will be favorable.

Impacts to human health from Site activities potentially affect both workers and the public and may result from exposure to radioactive materials, hazardous chemicals, or, for the worker, from physical hazards. The following sections compare these impacts between the *baseline* case and *closure* case, first for radiological impacts to workers and the public, then for nonradiological impacts to workers and the public.

Criteria for the significance of impacts vary depending on the hazard and receptor being analyzed. For individual workers and members of the public, there are standards and guidelines against which radiological exposure and incidence of physical injury or illness are compared. For hazardous chemical exposure, EPA guidance can be used only as a rough indicator of risk from exposure to a combination of chemicals. For collective exposure of the worker or general population, there are no standards, and results are primarily useful for comparison between the *baseline* case and *closure* case. Bases for comparison are presented in their respective sections and are also discussed in Section 4.8, "Human Health and Safety."

5.8.1 Radiological Impacts on Worker Health and Safety

In the course of normal operations, Site radiation workers are exposed to radiation in a controlled manner. Worker exposure is generally divided into the two broad categories of internal and external exposures (see Section 4.8.1, "Radiological Health and Safety–Worker"). Internal exposures occur when radioactive particles are ingested, inhaled, or taken in through a contaminated wound. As a result of stringent protective measures, procedures, and training, internal exposures at the Site are infrequent and typically occur only under abnormal or accident conditions.

External exposures occur primarily as a result of direct radiation emitted from radioactive materials. Workers who perform their jobs in the presence of gamma, neutron, or beta radiation sources receive external doses. External dose may be reduced by radiation protection measures and procedures, but a certain amount of exposure will continue to occur at the Site as long as SNM is stored. This section compares the *baseline* case and *closure* case with respect to estimated radiation dose that workers would receive from external sources for the described major activities.

An analysis was performed to estimate and compare the external dose to Site radiation workers as a group (called collective dose) between the *baseline* case and *closure* case. It is generally assumed that under the *baseline* case and *closure* case, individual workers would be protected in accordance with the Site's 750 millirem per year individual dose administrative control level. However, residue stabilization and certain activities such as building deactivation will be difficult to accomplish under this constraint. The site ALARA program can adjust the administrative control level within the constraints of the program to allow work to be accomplished. Doses would be maintained below the DOE limit of 5 mrem per year.

Total effective dose equivalent (the dose measure used) accounts for total health risk from radiation exposure regardless of which body tissues receive the dose or the sources or types of ionizing radiation producing the dose. Radiation worker risk is expressed in terms of "excess latent cancer fatality per rem of radiation dose received" (ICRP 1991a). The health effects conversion factor for the worker population is 4×10^{-4}, which when applied to a population, produces a result in "units of excess number of latent cancer fatalities per person-rem of radiation dose." Estimated doses to Site workers for the *closure* case are presented in Table 5.8-1.

Table 5.8-1. Worker Radiological Dose Estimates for *Closure* Case

Activity	Worker Dose (rem CEDE)		
	Maximum in any one year	Peak Year (1998)	Closure Case Total
SNM Management	93	93	426
Residue Management	249	249	1246
Building 371 Cluster DD&D and ER	17	N/A	71
Building 707 Cluster DD&D and ER	7.3	N/A	39
Building 771 Cluster DD&D and ER	19	2.6	81
Building 776 Cluster DD&D and ER	25	N/A	132
Building 779 Cluster DD&D and ER	5.0	4.0	17
Building 881 Cluster DD&D and ER	8.4	N/A	25
Building 886 Cluster DD&D and ER	4.1	3.2	14
Building 991 Cluster DD&D and ER	2.1	N/A	4.2
Miscellaneous Production Zone DD&D & ER	0.1	N/A	7.8
TRU Storage	44	44	572
TRU Shipping to WIPP	22	22	330
TRU Cluster DD&D and ER	0.1	N/A	0.3
Industrial Zone DD&D and ER	1.6	N/A	3.3
Buffer Zone DD&D and ER	0.1	N/A	0.2
Total Dose (Effective Dose Equivalent)	**N/A**	**417**	**2969**

In the *baseline* case, annual dose is lower because SNM management activities continue at minimal levels as needed, and very little remediation or DD&D activities occur. As discussed in Section 4.8 "Human Health and Safety" the 1996 actual cumulative dose to site workers was 263 person rem (or approximately 0.1 additional cancers would be experienced under the *baseline* case). Increases in dose would occur under the *closure* case to a peak annual dose of 417 person mrem as a result of remediation, SNM consolidation activities, residue stabilization, and DD&D, with approximately 0.2 additional cancer predicted for the radiation worker population as a result of one year's dose.

Annual collective radiological dose and associated excess latent cancer fatality rates are estimated to be low relative to weapons production years, as shown in Table 5.8-2. This data is not comparable to that shown in the 1980 Final Environmental Impact Statement, which was presented for a number of individuals exceeding various dose levels, rather than collective dose estimates.

Methodology

Radiological doses were estimated on an annual basis for both the *baseline* and *closure* cases. The dose estimates are intended to encompass all activities at the Site using the methodology described below.

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Table 5.8-2. Collective Dose and Risk Estimate to Workers

Year	Collective Dose (person-rem)	Risk of Latent Cancer Fatality
1977	270	0.11
1978	339	0.14
1979	471	0.19
1980	827	0.33
1981	877	0.35
1982	1173	0.47
1983	1142	0.46
1984	1315	0.53
1985	1556	0.62
1986	1407	0.56
1987	880	0.35
1988	654	0.26
1989	412	0.16
1990	769	0.31
1991	312	0.12
1992	297	0.12
1993	219	0.09
1994	215	0.09
1995	249	0.10
1996	263	0.11
1997	357	0.14
1998	417	0.17
1999	348	0.14
2000	342	0.14
2001	335	0.13
2002	211	0.08
2003	85	0.03
2004	90	0.04
2005	90	0.04
2006	130	0.05
2007	148	0.06
2008	127	0.05
2009	97	0.04
2010	103	0.04
2011	55	0.02
2012	54	0.02
2013	9.4	0.004
2014	9.2	0.004
2015	0.2	0.00008

Radiation dose Cumulative impacts are described separately in Section 5.15, "Cumulative Impacts" to workers from external sources is the primary route of exposure and is measured using dosimeters. Dose from internal exposure is measured and calculated using bioassay techniques. Jobs are analyzed individually to determine engineered controls and levels of personal protective equipment that are required. Respiratory protection devices, which reduce inhalation exposure by a factor of up to 10,000 times, are available and used as necessary (EG&G 1990c). As a result of these physical protective measures, procedures, and training, internal exposures are infrequent and very low; therefore, this analysis examines only dose from external sources. Radiation exposure and human health effects are explained in Section 4.8.1, "Radiological Health and Safety–Worker." A more thorough explanation of radiation exposure, its correlation to dose, and health physics principles is included in Appendix B "Human Health and Safety."

The basis for this analysis is the 1996 Site worker dose. In 1996, radiation workers at the Site received a collective dose of 263 person-rem. A detailed analysis of CY94 worker dose was performed by group, using the *Whole Body Dose Report* (EG&G 1995h). The groups of workers who collectively received more than 85% of that dose were identified from this report (such as waste treatment and packaging workers and radiological control technicians). These groups, along with their respective 1994 and projected doses, are identified in more detail in Appendix B "Human Health and Safety." The results of this CY94 analysis were scaled up to reflect CY96 site worker dose levels.

Based on the premise that future dose from ongoing Site operations would be related to past dose, managers or designees from the identified organizations were interviewed to determine 1) which activities were performed in 1994 that were responsible for most of their dose, 2) how these activities would change under various *baseline* and *closure* cases, and 3) an appropriate scaling factor to apply to the 1994 dose to estimate the annual dose for the organization during the alternative period.

In most cases, managers generated scaling factors based on their knowledge of 1994 work, understanding of future tasks and interim actions, and professional experience and judgment. Scaling factors were multiplied by the *baseline* dose to arrive at dose estimates for the *closure* case by organization. The results from this approach are semi-quantitative and should not be considered precise. The results provide a reasonable bounding estimate that is sufficient to support comparisons in the *baseline* case and *closure* case. The exposure levels reported for each organization should not be used individually because they are valuable only as a part of the entire analysis, which provides a basis for qualitative statements and conclusions.

Radiological doses that would result from planned future activities that were not performed in 1994 were estimated using different methodologies and then added to the totals from the methodology described above. These activities are environmental restoration, DD&D, construction and operation of a vault for storage of SNM, and SNM and residue stabilization activities. The methodologies, assumptions, and analyses used to estimate dose from these activities are included in Appendix B "Human Health and Safety."

Radiological dose to the remaining radiation worker population not accounted for in the interview process was also estimated separately. This estimate was developed according to the Site population projections developed in the socioeconomics analysis described in Section 5.13, "Impacts on Socioeconomics." A scaling factor for the *baseline* case and *closure* case and time period was developed by dividing the estimated Site population by the 1994 Site population. These scaling factors were then multiplied by the dose for the remaining workers for 1994. The methodology assumed a direct correlation between dose and number of workers.

Radiological doses from residue stabilization and SNM and residue related actions are consistent with the environmental assessments for the actions.

A potential contributor not factored into the approach is the future increase in concentrations of americium-241 that would result from radioactive decay of plutonium-241. Because americium-241 emits higher levels of gamma radiation than plutonium-241, sources of external radiation are slightly increasing at the Site. The effect of this phenomenon is included in the *baseline* case

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because the 1994 exposure data is partially from americium. However, continued ingrowth was not estimated for the *closure* case timeframe, although, this effect is expected to result in only a small percentage increase over the next decade while plutonium and residues are being stabilized and repackaged. The conservative estimations of dose are still expected to provide a bounding estimate of worker radiation dose. An increase in neutron exposures has also been observed as a result of aging and isotopic degradation of impure materials such as residues. A brief, qualitative description of these effects is included with the results of the worker dose analysis.

Comparison of Worker Dose Impacts

Results from the analysis are interpreted qualitatively in the following discussion, which compares and contrasts the *baseline* and *closure* cases with respect to worker dose and explains the dose estimates as presented in Table 5.8-1 above.

The *baseline* case represents a continuation of *baseline* conditions with the exception of a decrease in plant population. Baseline activities included continued thermal stabilization of at-risk plutonium metals and oxides in Building 707, some actinide solution stabilization and SNM consolidation into Building 371. residue and waste management, minor environmental remediation, and DD&D activities.

It is important to note that dose estimates are representative of only normal operations. Under this *baseline* case, it is expected that the potential for accidents or abnormal conditions such as package, piping, and tank breaches would increase and that worker exposures from both external and internal sources would be likely to increase. The risks associated with failure to perform recommended SNM-related activities that constitute the SNM and residue related actions are documented in the *DOE Plutonium Working Group Report on Environmental, Safety and Health Vulnerabilities Associated with the Department's Plutonium Storage* (DOE 1994n). Accidents are addressed separately in the *baseline* and *closure* cases in Section 5.14, "Impacts Resulting from Potential Accidents."

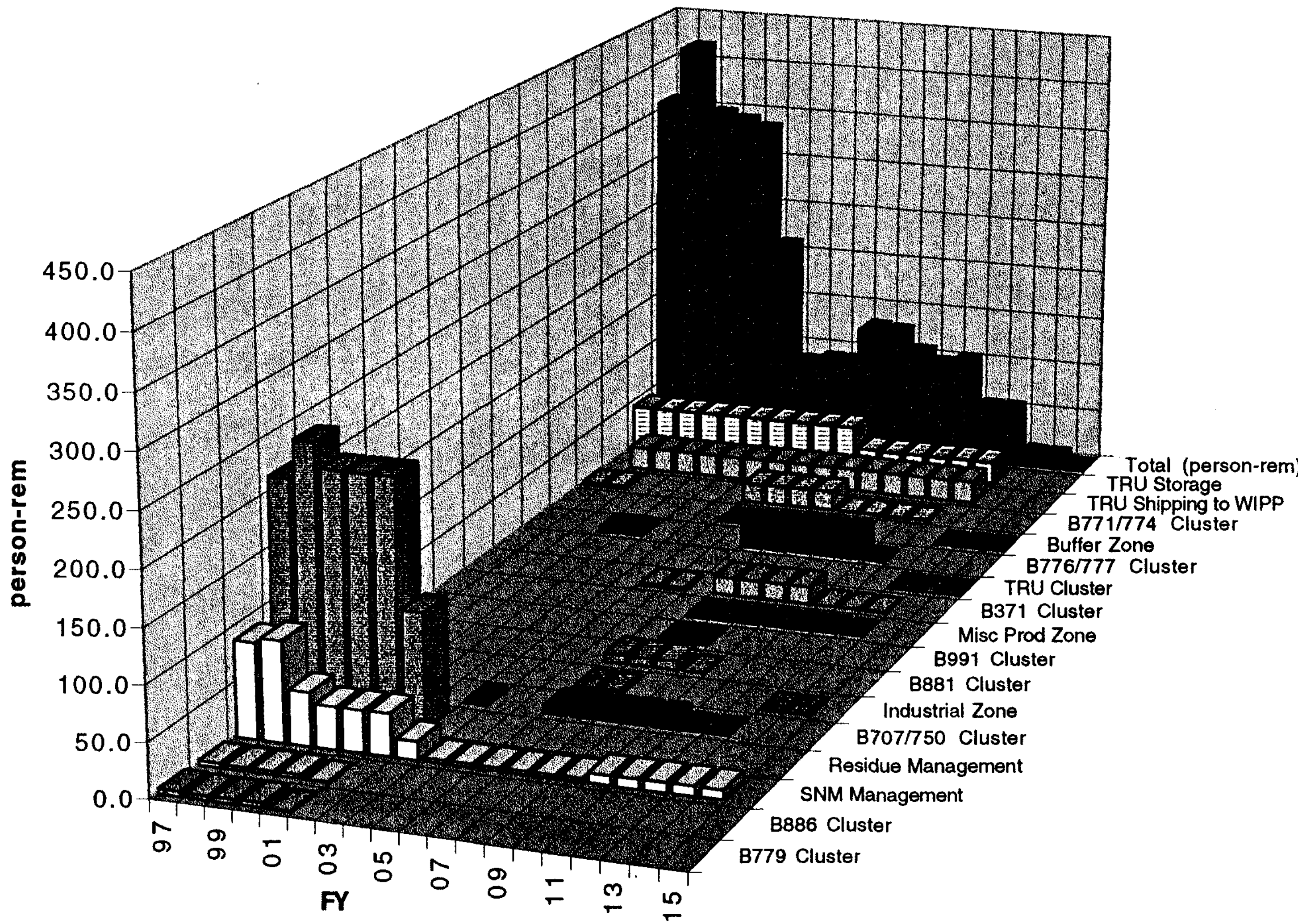
The *baseline* case reflects worker dose consistent with 1996 Site mission of risk reduction through SNM consolidation, limited reprocessing, safe storage and facility maintenance. Worker dose results from routine Site operations.

The *closure* case reflects increased worker dose associated with additional SNM and residue handling, reprocessing, and the loading of the Interim Storage Vault. Additional Site closure activities including environmental remediation, facility DD&D and the resulting waste disposal result in increased worker dose.

A worker dose profile during the full closure timeframe is shown in Figure 5.8-1. This indicated that the greatest dose to facility workers is from Building 707 SNM and residue stabilization and repackaging activities. The next largest contribution is the residue storage dose from high-americium residues in Building 776/777. Spikes during specific years can be seen for shipping enriched uranium off-site from B991, and SNM consolidation and off-site shipping.

The primary sources of worker dose under the *closure* case are increased routine operations, environmental remediation, and SNM and residue stabilization and repackaging. Routine operation increases result primarily from waste handling activities. Additional support and oversight efforts also contribute to routine operations worker dose. Environmental remediation and the handling of waste generated by these activities will result in worker dose. Facility DD&D will also result in worker dose over many years as the various facility clusters are remediated. A worker dose of 100 person-rem will result during FY07, the highest year of DD&D and ER activity which is about one-fourth of the peak year dose during SNM and residue stabilization and repackaging. The processing of SNM and Residue materials will result in significant worker dose, resulting in most of the 418 person-mrem dose in the peak year of closure activities (1998). This results from worker handling of large quantities of materials during the processing activities.

Figure 5.8-1 Worker Dose Profile



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The comparison of the *baseline* case with the *closure* case is presented in Table 5.8-1. Here a comparison of the worker dose breakdown and totals may be observed. Table 5.8-2 shows the historical record of worker doses since 1977, and projections for future years during the closure timeframe.

Co-Located Worker

An analysis was also performed with respect to the co-located worker. The co-located worker is an on-site worker who is not considered as being directly involved in radiological operations but who might receive radiological dose by working at the Site. The only substantive pathways involving the co-located worker are inhalation of airborne radionuclides and external exposure from on-site radioactive material movements. The latter is analyzed as part of Section 5.6, "Impacts on Traffic and Transportation."

Dose to the co-located worker under both cases was based on the air modeling analysis reported in Section 5.5.1, "Impacts on Radiological Air Quality." Exposures to the co-located worker reflect exposure to emissions without the benefit of respiratory protection. According to the air modeling analysis, the maximally exposed co-located worker would be located immediately east of the 903 Pad, Mound Area. In the dose calculation, it was assumed that this individual resides at this location continuously for the one-year time period being evaluated. This is a conservative assumption, which resulted in a bounding estimate of dose to the co-located worker. These results are summarized in Table 5.8-3.

In the *baseline* case, activities would continue at a minimal level, similar to *baseline* conditions. Accordingly, air emissions and resultant dose would be low and comparable to dose under *baseline* conditions. In the *closure* case, SNM related actions, residue stabilization, and environmental remediation activities would be the primary contributors to dose, resulting in an increase in dose to the co-located worker. This impact would be temporary, and doses would return to approximately the *baseline* level or below after completion of these activities.

5.8.2 Radiological Impacts on Public Health and Safety

As described in Section 4.8.2, "Radiological Health and Safety–Public," several potential pathways exist for radiological exposure to the public. The primary pathway and the pathway that can be most affected by the *baseline* and *closure* cases is the air transport pathway. The impacts of the *baseline* and *closure* cases on air quality and methodologies used to determine these impacts are described in Section 5.5.1, "Impacts on Radiological Air Quality." They are also summarized in the following section in context with other pathways to the public. For the maximally exposed off-site individual, surface water, ground water, ground-plane irradiation, and soil ingestion were also considered qualitatively. Dose and risk estimates to the maximally exposed off-site individual were made for the *closure* case. Risks to the maximally exposed off-site individual (a member of the public) are contrasted in Table 5.8-4.

During the *closure* case, an increase in dose would be expected as a result of the contaminants released during remediation operations and SNM and residue related activities. However, doses would be well below the 10 millirem per year standard established in the Clean Air Act; thus none of the *closure* case impacts are considered substantial.

The air pathway is the primary pathway by which the general public within a 50-mile radius of the Site would be affected by radioactive releases. As with the maximally exposed off-site individual, air modeling was used to quantitatively evaluate impacts from the *baseline* and *closure* cases. Collective dose to the general public was calculated for the approximately 2.7 million population within 50 miles of the Site predicted for 2006[1]. Comparison of dose during the *closure* case and *baseline* case are shown in Table 5.8-5.

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[1] *This estimate is higher than the Denver metropolitan population discussed in Section 5.12, "Impacts on Socioeconomies." For estimates beyond 2006, the population growth would be assumed to continue at the growth rate discussed in Section 5.12 (e.g., could increase to approximately 3 million people by the end of the closure case timeframe.)*

Current radioactive releases from the Site are minimal and pose minimal risk to the general public. Efforts to reduce area sources of contamination in the *closure* case would result in higher doses to the public during the activities, although these higher doses would not present substantial additional risk. Residue stabilization and SNM-related activities would also contribute to the higher doses in the *closure* case. Releases at the completion of the *closure* case would be lower than *baseline*. The decrease would have a negligible effect on health risk to the public because the contribution to public health risk would be minimal even during the *closure* case in comparison to other sources of radiation to the public. These other sources of radiation are discussed with respect to cumulative impacts in Section 5.15, "Cumulative Impacts."

Table 5.8-3. Estimated Annual Dose and Increased Probability of Latent Cancer Fatality to the Maximally Exposed Co-Located Worker

Maximally Exposed Co-located Worker	Annual Dose (millirem/year)	Excess Latent Cancer Fatalities
Baseline Case	0.29	3×10^{-9}
Closure Case	5.4	2×10^{-6}

Table 5.8-4. Comparison of Dose to the Maximally Exposed Individual via the Air Pathway

Maximally Exposed Individual	Annual Dose (millirem/year)	Excess Latent Cancer Fatalities
Baseline Case	0.0052	3×10^{-9}
Closure Case	0.23	1×10^{-7}

Table 5.8-5. Comparison of Collective Dose to the General Public via the Air Pathway for *Baseline and Closure Cases*

General Public Population Within 50 Miles	Annual Dose (person-rem/year)	Excess Latent Cancer Fatalities
Baseline Case	0.27	1×10^{-4}
Closure Case	23	0.01

Methodology for Comparing Health Risk to the Maximally Exposed Off-Site Individual

Exposure to the maximally exposed off-site individual was compared between the *baseline and closure* cases on the basis of the air transport pathway. Subsequent ingestion of soil contaminants or exposure to ground-plane irradiation from deposition of radioactive contaminants is also considered as part of the dose from the air transport pathway. The basis for estimating these exposures is described in Section 5.5.1, "Impacts on Radiological Air Quality."

RECEPTORS. For this analysis, two human receptors were considered: the maximally exposed individual and the general public. The maximally exposed individual is a hypothetical person who resides near the Site at a hypothetical location where maximum dose from the air pathway is received. This individual is assumed to reside at this location 24 hours per day, 365 days per year for a 70-year lifetime. In reality, maximum concentrations of radiological contaminants do not occur for the air pathway at the same geographic location, and an individual would not remain at the location on a continuous basis. Therefore, the maximally exposed individual demonstrates the worst case but is not truly representative of any actual member of the public.

Dose to the general public was evaluated in terms of collective dose. As required by DOE Order 5400.5, "Radiation Protection of the Public and Environment," collective dose was calculated for the population residing within a 50-mile radius from the center of the Site. The population within this radius is 2.7 million people for the Denver Metropolitan Area predicted for 2006. Collective dose was calculated as the average radiation dose to an individual in a specified sector of the total area and multiplied by the number of individuals in that sector. The unit used to quantify collective dose is person-rem.

CALCULATED HEALTH EFFECTS FROM PUBLIC DOSES. Estimation of health effects from radiological dose was based on the *1990 Recommendations of the International Commission on Radiological Protection* (ICRP 1991a), which presents a health effects conversion factor for risk of excess latent cancer fatality per rem of radiation dose received. The factor for the general public is 5×10^{-4} which, when applied to individuals, is in units of "lifetime probability of fatal cancer per rem of radiation dose" (this factor is larger than the factor for workers because it includes more sensitive portions of the population, such as infants). When this factor is applied to populations and collective dose, the applicable units are "excess number of cancer fatalities per person-rem of radiation dose." This factor was used to calculate the increased risk of cancer to the maximally exposed individual from each pathway.

AIR/INHALATION. Inhalation of airborne releases is the one pathway with potential significance to the general public living within a 50-mile radius. As described in Section 5.5.1, "Impacts on Radiological Air Quality," radioactive air emissions occur from both building and area (contaminated soil) sources at the Site. Actual emissions are monitored at numerous locations and modeled according to EPA methodology (40 CFR 61Hb). For the *baseline* case and *closure* case, air pathway calculations for the maximally exposed individual and the collective dose to the public were based on modeling, as described in Section 5.5.1, "Impacts on Radiological Air Quality."

Comparative Analysis of Risk to the Maximally Exposed Off-Site Individual

In Section 4.8.2, "Radiological Health and Safety–Public," a bounding scenario estimate of risk to the maximally exposed off-site individual was made where the largest influence came from ground water. For this estimate, maximum radionuclide concentrations from the worst case ground water well in the upper hydrostratigraphic unit near the eastern Site boundary was assumed to be present in ground water pumped from an off-site well and ingested. At this time, adequate data to demonstrate whether or not contaminated ground water is actually migrating off-site are not available. Also, adequate flow would probably not be available from the upper hydrostratigraphic unit to supply a domestic well. Without more extensive ground water sampling data and a better understanding of the source of the contamination, it was not possible to quantitatively predict change in contamination levels in these wells nor in ground water immediately east of the Site boundary that might result from the *baseline* and *closure* cases. Based on existing results of ground water monitoring, it is believed that Site activities have had little effect on ground water quality along the eastern border of the Site. Before 1996, the hydraulic conductivity of the claystones between the uppermost aquifer and the lower aquifer was believed to be sufficiently low to ensure that Site contaminants could not have migrated vertically to the lower formations under the Site. In 1994, borehole correlation work indicated the potential for near-surface faults to exist (i.e., flow pathways may exist between the uppermost and lower aquifers). Additional hydrogeologic characterization is being performed to assess these potential pathways (Kaiser-Hill 1995a).

Ground water conditions would be expected to remain fairly static (due to the typically low velocity of ground water) during the *baseline* and *closure* cases with similar predicted risk to the maximally exposed off-site individual as reported in Section 4.8.2, "Radiological Health and Safety–Public." Impacts on ground water are described in more detail in Section 5.4.1, "Impacts on Ground Water Quality."

Surface water was initially considered in development of dose to the maximally exposed off-site individual in Section 4.8.2, "Radiological Health and Safety–Public." However, because the contamination levels in ground water were substantially higher and the receptor could only ingest

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one source at the daily rate, surface water was not included in the final calculation. Under the *closure* case, changes to surface water would follow the same trends as ground water. Contamination sources would be removed or immobilized, reducing future contamination of surface water. Again, predicted impacts are qualitative, and it is not instructive to include surface water in the quantitative comparative risk to the maximally exposed off-site individual. Impacts on surface water quality are discussed in more detail in Section 5.4.2, "Impacts on Surface Water Quality."

Soil ingestion and ground-plane irradiation were considered in Section 4.8.2, "Radiological Health and Safety–Public," with respect to the maximally exposed off-site individual. The values in Section 4.8.2 reflect prior off-site contamination and would remain fairly constant irrespective of the *baseline* and *closure* cases. For this reason, these values were not included in the comparative impact assessment to the maximally exposed off-site individual. Additional dose from soil ingestion and ground-plane irradiation as a result of the *closure* case was included in the air transport pathway dose.

Air modeling was used to predict air quality and dose to the maximally exposed off-site individual as a result of the *closure* case. Sources of airborne contamination include building operations (point sources), remediation operations (area sources), and resuspension of existing contamination (area sources). Impact from these sources in the *closure* case are described in Section 5.5, "Impacts on Air."

Table 5.8-4 above contrasts risk from the air pathway to the maximally exposed off-site individual. During the *closure* case, an increase in dose is observed as a result of the contaminants released during remediation operations, residue stabilization, and SNM and residue related actions. Upon completion of these operations, dose would fall slightly below the *baseline* as a result of reduced area source contamination levels and completion of the residue consolidation and SNM-related activities. During the *closure* case doses would be well below the 10 millirem/year standard established in the Clean Air Act and would not be considered substantial.

Comparative Analysis of Risk to the General Public

Table 5.8-5 above contrasts the estimated doses to the general public via the air transport pathway for the *closure* case. The air pathway is the only substantive pathway by which the general public within a 50-mile radius of the Site would be affected by radioactive releases. As with the maximally exposed off-site individual, air modeling was used to quantitatively evaluate impacts from the *closure* case. Dose to the general public was calculated collectively for the 2.7 million population of the Denver Metropolitan Area predicted for 2006.

There are no acceptability criteria for collective exposure to the general population. However, the results show the least impact under *baseline* with higher doses under the *closure* case, primarily as a result of performing the interim SNM actions and environmental restoration activities. The expected number of excess latent cancer fatalities among the population would be very low for the *baseline* and *closure* cases.

5.8.3 Nonradiological Impacts on Worker Health and Safety

Nonradiological worker health impacts were analyzed with respect to two categories. Occupational health impacts include injuries and illnesses that are sustained on the job and recorded according to OSHA regulations. In addition, workers are exposed to nonradiological air pollutants from Site operations and environmental contaminants while at the Site. Air modeling was used to determine the extent of this impact. Both types of impacts are described in the following sections.

Occupational Health Impacts

Workers at the Site are exposed to a variety of industrial hazards in addition to radiological hazards. These hazards include toxic chemicals, heavy machinery, repetitive motion tasks, and physical agents such as heat and cold. As described in Section 4.8.3, "Nonradiological Health and

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Safety–Worker," several programs are in place at the Site to prevent these hazards from causing worker injuries and illnesses. As the Site's activities change, the types of hazards and associated injuries would also change. The following section presents the types and numbers of injuries and illnesses that are predicted to occur under the *baseline* and *closure* cases. The methodologies used and estimated impacts are also summarized and discussed in more detail.

Statistical data from the Site's Occupational Health and Occupational Safety departments were used to calculate injury and illness incidence rates for Site workers by organization. These rates were then applied to the same organizations for the *baseline* and *closure* cases according to projected staffing levels from the *baseline* case and *closure* case socioeconomic analysis (Section 5.12, "Impacts on Socioeconomics"). It was assumed that organizational responsibilities being implemented by numerous subcontractors for the current Integrating Management Contractor (IMC) would continue at a rate no worse than the previous Management and Operating Contractor (M&O) and previous subcontractors. A general industry rate for construction was used to estimate injury and illness cases for DD&D and remediation. This rate, which is considerably higher than the historical incidence rate for the Site, was applied to all subcontractors involved in those activities for the *closure* case. A summary of the results is presented in Table 5.8-6.

Table 5.8-6. Summary of Estimated Worker Injury and Illness Cases

Description	*Baseline Case*	*Closure Case* - Peak Annual Number of Injuries and Illnesses	
	Number of Injuries and Illnesses	During High Activity Analysis Period	After High Activity Analysis Period
Site Contractor	244	175	17
Subcontractor	9	409	0
Site Total	**253**	**584**	**17**

<u>METHODOLOGY.</u> The analysis of worker health and safety from a nonradiological perspective was performed using Site data regarding illnesses and injuries from the past to predict the numbers of injuries and illnesses for similar activities in the future. For activities that were not performed frequently in the past, rates from general industry were used. New activities that would occur under the *baseline* and *closure* cases include construction-related activities for DD&D, and environmental remediation. Most of these activities would be performed by subcontractors not currently employed by the IMC team. The industry incidence rate for construction activities was used to estimate the numbers of illnesses and injuries for these subcontractors in the *closure* case.

Incident reporting information for the Site was obtained from the Site's Occupational Health and Occupational Safety departments (note: data for the IMC team that includes all subcontractors is not available, therefore, the previous M&O data was used). Recordable injury and illness cases were extracted from OSHA 200 log summary sheets. Total work hours by year were provided by the Site's Central Planning department. Based on records from 1990 through 1994, the average incidence rate for injuries and illnesses among contractor employees is 5.0 per 200,000 hours worked (200,000 hours worked are equivalent to 100 full-time employees at 40 hours per week for 50 weeks). The incidence rate was multiplied by the estimated number of hours to be worked for the *baseline* and *closure* cases to predict the number of cases. It was assumed that contractor employees (including all subcontractors currently under contract to the IMC team) work 2,000 hours per year. The incidence rate among incidental subcontractor employees to the previous M&O Contractor for the 1990-1994 time period is 5.2 per 200,000 hours worked. It was assumed that these subcontractor employees work 200 hours per year.

The Bureau of Labor Statistics provided data from general industry. Using data from 1988 through 1993, the average incidence rate for construction industries is 13.6 per 200,000 hours worked (USDL 1993b). This rate was applied to all subcontractor hours for the *closure* case. It should be noted that rates at DOE sites tend to be lower than general industry as a result of the

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extensive training and precautionary measures that are used at these sites to improve workplace safety. For this reason, the rate for the construction industries is considered to be conservative and probably results in overestimates of the number of cases that would arise at the Site during the *closure* case.

Numbers of cases for the *baseline* and *closure* cases were estimated for two time periods: a high activity period from the present to when most facilities have been DD&D'd, and a point in time after this period. The peak value anticipated for the *baseline* case and *closure* case evaluation timeframe was used.

COMPARATIVE IMPACT ASSESSMENT. Under the *baseline* case 253 injuries and illnesses would be predicted for the Site workforce.

For the *closure* case, overall Site population would decrease steadily during the high activity analysis period but the number of injuries and illnesses would double to 584 per year due to the type of construction and demolition activities. These total numbers of injuries are based on the assumption that the subcontractor incidence rates will be no worse than industry averages. However, with the Site's emphasis on health and safety of the worker it is expected that their performance will be much better than industry averages, resulting in much less than 584 injuries/illnesses per year. After the high activity analysis period, DD&D and remediation activities would be completed by the end of this timeframe, and SNM and waste would be consolidated into their respective new storage facilities. At this time, the Site population would decrease dramatically, and construction subcontractors would no longer be used. Total number of injuries and incidence rates would be expected to be much lower at this time. Additional information concerning the health and safety implications of new Site activities, including environmental remediation and DD&D, is included in Appendix C, "Accidents."

Another measure of worker safety is based on fatality rates. No fatalities have occurred at the Site since 1987 (i.e., an electrocution). The average fatality rate for DOE facilities from 1989 through 1993 is 2.9 fatalities per 100,000 employed. This rate is lower than the National Safety Council fatality rate for the private sector, which is 8.4 fatalities per 100,000 employed, averaged from 1989 to 1993 (DOE 1994m).

Air Pollutant Health Impacts (Nonradiological)

Concentrations of chemicals in air were predicted by modeling air emissions for the different Site operations presented for the *baseline* and *closure* cases. Potential risk to the co-located worker from contact with these air pollutants through direct inhalation was characterized to identify any potential for risk of adverse health effects or cancer.

The identification of possible human health risks to the co-located worker from the air release of criteria and hazardous air pollutants takes into account both the levels of chemicals potentially present and the harmful effects of the chemicals at these levels.

Potential human health effects from exposure to criteria and hazardous air pollutants may include cancer as well as a wide range of other health effects depending on the toxicology of the material. Noncancer health effects are evaluated in terms of a hazard quotient. Most noncancer health effects have a threshold dose, which is the amount of a particular toxic substance below which no adverse effect has been observed. The hazard quotient is the ratio of the exposure concentration to the concentration at which adverse effects are expected.

To assess the overall potential for noncancer effects posed by more than one chemical, a hazard index as developed by EPA was used (EPA 1989a). The hazard index sums the hazard quotients for individual chemicals. If the hazard index is calculated to be a number less than 1.0, then the estimated dose will be less than the threshold dose and no adverse human health effects are expected. If the hazard index is calculated to be a number greater than 1.0, then the estimated dose will be greater than the threshold dose and some adverse human health effects could be expected.

Table 5.8-7 presents the estimated risk of adverse health effects to the co-located worker at the Site from predicted air releases of criteria and hazardous air pollutants.

Table 5.8-7. Health Risk to the Co-Located Worker from Predicted Releases of Air Pollutants for *Baseline* and *Closure Cases*

Air Pollutants	Co-Located Worker Health Risks (Hazard Quotient)	
	Baseline Case	*Closure Case*
Criteria Pollutants[1]		
Carbon Monoxide (8-hour)	0.1	0.1
Lead (quarterly)	3×10^{-12}	3×10^{-12}
Nitrogen Dioxide	0.4	0.4
PM-10	0.02	0.1
Sulfur Dioxide	0.5	0.5
TSP	0.01	0.05
Hazardous air Pollutants		
Ammonia	2×10^{-3}	2×10^{-3}
Beryllium	2×10^{-3}	4×10^{-3}
Carbon Tetrachloride	7×10^{-4}	2×10^{-3}
Chlorine	8×10^{-3}	8×10^{-3}
Chloroform	6×10^{-4}	6×10^{-4}
Dioctyl Phthalate	1×10^{-4}	1×10^{-4}
Hydrochloric acid	7×10^{-4}	7×10^{-4}
Hydrofluoric acid	1×10^{-3}	1×10^{-3}
Hydrogen sulfide	7×10^{-3}	7×10^{-3}
Methyl Ethyl Ketone	-	2×10^{-5}
Methylene Chloride	5×10^{-6}	1×10^{-5}
Nitric acid	7×10^{-3}	7×10^{-3}
1,1,1,-Trichloroethane	2×10^{-3}	2×10^{-3}
Total Risk (Hazard Index)[2,3]	**1.1**	**1.2**

[1]Health risk for hazardous chemicals is the ratio of the air concentration to the OSHA Permissible Exposure Limit. Exposure limits are the 8-hour time-weighted average air concentration.

[2]Total risk implies health effects are additive and the individual is chronically exposed to all chemicals simultaneously.

[3]Both TSP and PM-10 measure dust concentrations with some overlap; only PM-10 is included in the hazard index because its contribution to health effects is more important.

Hazard indices resulting from bounding scenarios predicted for exposure to air pollutants for the *baseline* and *closure* cases show a possibility for adverse health effects to the on-site co-located worker from a combination of individual chemicals.

The hazard index is slightly higher for the *closure* case as a result of the large amount of remediation, treatment of remediation waste, and building demolition activity. These activities would occur over a relatively short period of time and result in increased dust and organic compound emissions.

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The primary contributors to this hazard index are criteria pollutants, specifically carbon monoxide, nitrogen dioxide, and sulfur dioxide, which all result from fuel combustion primarily from diesel generators. Identification of pollutant sources was conducted in a very conservative manner, which results in an overestimate of risk for both the *baseline* and *closure* cases.

Conservatisms include modeling simultaneous releases from all permitted emission sources at their maximum permitted levels as if they were emitted from one hypothetical location. In addition, ambient pollutants are included as well as the Site contribution. As a result, there is little variation in air quality for the *baseline* and *closure* cases. The differences are not substantial.

Potential cancer risk to the Site co-located worker from modeled air releases of carcinogenic (cancer-causing) air pollutants is presented in Table 5.8-8.

Table 5.8-8. Cancer Risks to the Co-Located Worker from Predicted Releases of Carcinogenic Air Pollutants for *Baseline* and *Closure Cases*

Air Pollutants	Cancer Risk to Co-Located Worker[1]	
	Baseline Case	***Closure Case***
Beryllium	9×10^{-7}	2×10^{-6}
Carbon Tetrachloride	1×10^{-5}	3×10^{-5}
Chloroform	1×10^{-5}	1×10^{-5}
Methylene Chloride	4×10^{-7}	1×10^{-6}
Total Cancer Risk	$\mathbf{3 \times 10^{-5}}$	$\mathbf{5 \times 10^{-5}}$

[1]Intake for a worker multiplied by the EPA slope factor. Intake based on 8 hours/day, 250 days/year (EPA 1989a).

Scenarios postulated for the maximum estimated air release of carcinogens from the Site show a negligible impact on an individual's cancer risk. The total cancer risk is within EPA guidelines (EPA 1990b).

METHODOLOGY. Potential sources of chemical releases from the Site include air releases from normal operations, including point sources (building stacks or vents) and fugitive emissions (contaminated soils). All other forms of air releases are assumed to be prevented under normal operations. Air emissions data and details on air modeling are presented in Section 5.5.2, "Impacts on Nonradiological Air Quality," and in Appendix B "Human Health and Safety." Risks from exposure to hazardous chemicals via the air pathway were evaluated for potential hazardous air (adverse health effects) and cancer impacts on a co-located worker. Co-located workers are Site workers who do not necessarily perform work that results in chemical exposure, but by their presence at the Site may be exposed to releases that occur. The risk of adverse health effects from exposure to hazardous chemicals is expressed as a comparison between intake levels predicted and intake levels known to be safe.

For the air pathway, concentrations of specific chemicals of concern at on-site locations were predicted using the Industrial Source Complex-2 computer code. The maximum predicted air concentrations were extracted from the modeling results and used to estimate the bounding scenario risk from exposure through inhalation. The bounding scenario on-site was for a co-located worker continually located at the hypothetical point on-site where the maximum concentration of all the air pollutants occurred simultaneously. Direct inhalation also represents the maximum intake to the individual. This scenario is not expected to occur because it is unlikely that exposure to all air pollutants would occur at the same time throughout the co-located worker's entire time working at the Site.

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Air is the only pathway to potentially affect the co-located worker. Air pollutants were selected on the basis of screening criteria presented in Section 5.5.2, "Impacts on Nonradiological Air Quality." The co-located worker is assumed *not* to wear personal protective equipment, and predicted intake is for a bounding scenario of a 154-pound adult inhaling 20 m^3 of air per day. The co-located worker is assumed to work 8 hours per day for 50 weeks per year for 30 years. These methods are consistent with the EPA's *Risk Assessment Guidance for Superfund* (EPA 1989a). Details on the application of these methods are presented in Appendix B "Human Health and Safety."

For health effects other than cancer, the numerical estimate of risk is the *hazard quotient*, which, for the co-located worker, is the ratio of the predicted intake at the Site to the OSHA permissible exposure limit. The permissible exposure limits are levels of safety for long-term exposure in an 8-hour per day duration. This applies to chemicals that do not cause cancer but still may impact worker health. Below this level of exposure (reference dose), it is unlikely for even sensitive populations to experience adverse health (non-cancer) effects. If the individual's intake exceeds this threshold, there may be concern for potential adverse health (non-cancer) effects. However, the level of concern would not increase linearly as the threshold is reached or exceeded because these threshold values are not based on the same severity of toxic effects and the effects would be chemical-specific.

For cancer-causing chemicals, the EPA chemical-specific *cancer slope factor* multiplied by the predicted intake (based on 8-hour work day exposures) estimates the individual's excess lifetime risk of cancer (the increase in probability of getting cancer). The calculation of cancer risk converts estimated daily intake averaged over a lifetime of exposure directly to incremental risk of an individual developing cancer. The slope factor assumes a linear dose response between intake and increased incidence of cancer. Because these slope factors are conservatively estimated, the "true" risk would not exceed the estimated risk and is likely to be less than that predicted (EPA 1989a). This is a very conservative estimate of cancer risk for the adult worker because the EPA slope factors are based on the general population, including sensitive populations such as infants and the elderly. The *National Contingency Plan* (EPA 1990b) stated guidelines for acceptable risk. Risk less than 1 in 1 million (10^{-6}) is considered acceptable, risk between 1 in 1 million and 1 in 10,000 (10^{-4}) may be acceptable, and risk greater than 1 in 10,000 is not considered acceptable per the EPA.

COMPARATIVE IMPACT ASSESSMENT. This comparative analysis contains a review of the estimated risk from the potential release of chemicals via the air pathway for each of the *baseline* and *closure* cases.

Air modeling results predicted contaminant concentrations in air at specific locations at the Site. The location where the maximum concentration was predicted at the Site varied for each chemical modeled. The total risk calculated for the co-located worker conservatively assumes that the exposed individual is in a hypothetical location where all chemicals are at their highest predicted concentrations simultaneously. This condition would not likely exist but represents the bounding scenario for air exposure. It is assumed that if the bounding scenario risk was very low, then a more realistic exposure scenario would result in an even lower risk to the on-site worker.

Table 5.8-7 above presented the estimated adverse health (non-cancer) risk to the co-located worker from predicted releases of hazardous air pollutants for the *baseline* and *closure* cases which are not considered substantial impacts. Results of the air modeling showed very little change in the emission rates of hazardous air pollutants between the *baseline* and *closure* cases. Air emissions for the *closure* case by the additional release of new chemicals not released under the *baseline* case. However, overall risk to human health did not change substantially for the *closure* case with additional releases. A more substantial change (increase or decrease) in air emissions would have to occur for the overall human health risks to vary in magnitude to allow differentiation of impacts on the on-site co-located worker between the *baseline* and *closure* cases.

Table 5.8-8 above presented cancer risks to the co-located worker from predicted air releases of carcinogenic (cancer-causing) chemicals under the *baseline* and *closure* cases. Cancer risk calculated for the co-located worker utilized EPA chemical-specific slope factors. This is a very

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conservative estimate of a worker's additional risk of getting cancer because these values are applicable to the general public, including sensitive populations such as infants and the elderly. The worker population is more likely a healthy adult population. Therefore, risk to the co-located worker is likely to be lower than these estimates which is a negligible impact on an individual's cancer risk.

The risk of cancer for the co-located worker is similar between the two cases, as are non-cancer health impacts. The changes in air emissions for carcinogens did not vary enough to distinguish cancer risk between the *baseline* and *closure* cases. Even these bounding scenarios predicted for air release of carcinogens from the Site show a negligible impact on an individual's cancer risk and are even within the acceptable range (10^{-6} to 10^{-4}) as presented in the EPA's *National Contingency Plan* guidelines (EPA 1990b).

5.8.4 Nonradiological Impacts on Public Health and Safety

Nonradiological public health impacts from the potential release of hazardous chemicals from the Site were evaluated. The air pathway was the only pathway analyzed under the *baseline* and *closure* cases. The ground water, surface water, and soil pathways were determined to be incomplete exposure pathways to the off-site public. Ground water is not used as a source of drinking water, surface water is restricted from access, and contaminated soils have been stabilized or otherwise restricted from access. Although activities identified in the *baseline* and *closure* cases may impact ground water, soils, and surface water off-site, those potential impacts are not expected to change conditions off-site during the timeframe of the *closure* case analyses.

Air Pollutant Health Impacts (Nonradiological)

Concentrations of chemicals in air were predicted by modeling air emissions for the different Site operations presented in each alternative. Potential risk to the public from contact with these air pollutants through direct inhalation was characterized to identify any potential for adverse health effects, including chemical toxicity and cancer risk. The human health risk estimates take into account both the levels of chemicals potentially present and the harmful effects of the chemicals at these levels. Table 5.8-9 presents the estimated health risk to the maximally exposed off-site individual (a member of the public) from predicted air releases of criteria pollutants and hazardous chemicals for the *closure* case.

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Table 5.8-9. Maximally Exposed Off-Site Individual Health Risk from Predicted Releases of Air Pollutants

Air Pollutants	Maximally Exposed Individual Health Risk (Hazard Quotient)	
	Baseline	*Closure Case*
Criteria Pollutants[1]		
Carbon Monoxide (8-hour)	0.4	0.4
Lead (quarterly)	3×10^{-14}	3×10^{-14}
Nitrogen Dioxide	0.2	0.2
PM-10	0.3	0.4
Sulfur Dioxide	0.1	0.1
TSP	0.4	0.6
Hazardous Air Pollutants[2]		
Ammonia	9×10^{-5}	9×10^{-5}
Benzo(a)pyrene	–	0.03
Beryllium	N/A	N/A
Carbon Tetrachloride	5×10^{-3}	6×10^{-3}
Chlorine	0.02	0.02
Chloroform	N/A	N/A
Dioctyl Phthalate	2×10^{-5}	2×10^{-5}
Hydrochloric acid	8×10^{-4}	9×10^{-4}
Hydrofluoric acid	4×10^{-3}	4×10^{-3}
Hydrogen sulfide	0.02	0.02
Methyl Ethyl Ketone	–	2×10^{-6}
Methylene Chloride	1×10^{-6}	2×10^{-6}
Nitric acid	0.2	0.2
Tetrachloroethylene	–	5×10^{-6}
1,1,1,-Trichloroethane	2×10^{-5}	2×10^{-6}
Total Risk (Hazard Index)[3, 4]	**1.3**	**1.5**

[1]Hazard quotient for criteria pollutants is the ratio of predicted air concentrations to National Ambient Air Quality Standards, 40 CFR 50, except for TSP which compares to Colorado Ambient Air Quality Standards, Reg. 14
[2]Health risk for hazardous chemicals is the ratio of the individual's intake to EPA's inhalation reference dose (intake is for the bounding scenario; a 70-kg adult, inhaling 20 m^3 of air per day, 365 days per year for 70 years) (EPA 1989a).
[3]Total risk implies health effects are additive and the individual is chronically exposed to all chemicals simultaneously.
[4]Both TSP and PM-10 measure dust concentrations with some overlap; only PM-10 is included in the hazard index because its contribution to health effects is more important.

Exposures from hypothetical bounding scenarios were used to estimate the possible human health risk from air emissions. The bounding scenario analyzed for exposure to air pollutants from the Site was for an individual continually located at the point adjacent to the Site boundary where the maximum air concentrations of all contaminants were predicted. This assumed simultaneous exposure to all air pollutants is not a likely scenario but represents the worst possible exposure conditions.

The bounding scenario shows a possibility for adverse health effects from individual chemicals to occur to the off-site individual located near the Site boundary. The hazard index for each alternative is slightly greater than one, thus indicating there may be concern for potential noncancer effects. As a rule, the greater the hazard index is above one, the greater the level of concern (EPA 1989a).

The primary source of pollutants is criteria pollutants. Criteria pollutant concentrations for this analysis are based on modeled Site contributions plus ambient concentrations in the area as measured at locations that vary by pollutant. In most cases, concentrations, and therefore the hazard index, are more representative of background conditions than of the contribution from the Site. Additionally, ratios of criteria pollutant concentrations to their standards are not typically summed for the evaluation of air quality. As long as each individual pollutant is below its standard level, air quality is considered acceptable. For these reasons, a hazard index greater than one is not of concern, and this number should be used as a basis against which to compare the *baseline* and *closure* cases rather than as an indication of absolute risk.

Potential cancer risk from modeled air releases of carcinogenic (cancer-causing) chemicals is presented in Table 5.8-10 for the maximally exposed off-site individual.

Table 5.8-10. Maximally Exposed Off-Site Individual Cancer Risk from Predicted Releases of Carcinogenic Air Pollutants for *Baseline and Closure Case*

Air Pollutants	Maximally Exposed Off-Site Individual Cancer Risk[1]	
	Baseline	*Closure Case*
Benzo(a)pyrene	–	2×10^{-8}
Beryllium	1×10^{-10}	6×10^{-10}
Carbon Tetrachloride	2×10^{-7}	2×10^{-7}
Chloroform	7×10^{-8}	7×10^{-8}
Methylene Chloride	2×10^{-9}	3×10^{-9}
Tetrachloroethylene	–	1×10^{-9}
Total Cancer Risk[2]	$\mathbf{2 \times 10^{-7}}$	$\mathbf{3 \times 10^{-7}}$

[1]Cancer risk for hazardous chemicals is the product of the individual's predicted intake multiplied by EPA's cancer slope factor. Intake was calculated for the bounding scenario; a 70-kg adult, inhaling 20 m^3 of air per day, 365 days per year for 70 years (EPA 1989a).
[2]Total cancer risk assumes that the carcinogenic effects of these chemicals are additive and that the individual is chronically exposed to all chemicals simultaneously.

Table 5.8-10 presents cancer risk for the maximally exposed off-site individual from the maximum air concentrations modeled for chemicals released. These estimated cancer risks are below EPA's guidance of 10^{-6} (1 in 1 million increase in cancer), indicating no cause for concern.

METHODOLOGY. The general public within a 50-mile radius of the Site is potentially exposed to hazardous chemicals through air, surface water, and ground water releases from the Site. Potential risk to the public from contact with these chemical levels via inhalation or ingestion was characterized to identify any potential for adverse health effects, including chemical toxicity and cancer risk. Cancer risk is expressed as the individual's excess chance of getting fatal cancer in a lifetime. The risk of adverse health effects from exposure to hazardous chemicals is expressed as a comparison between intake levels predicted for the Site and intake levels known to be safe.

Potential sources of chemical releases from the Site include air releases from normal operations, including point sources (building stacks or vents) and fugitive emissions (contaminated soils). All other forms of air releases are assumed to be prevented under normal operations. Air emissions data and details on air modeling are presented in Section 5.5.2, "Impacts on Nonradiological Air Quality," and in Appendix B "Human Health and Safety."

For the air pathway, air concentrations of specific chemicals of concern at off-site locations were predicted using the Industrial Source Complex-2 computer code. Selection of the specific chemicals was identified in Section 4.5.3, "Nonradiological Air Quality." The maximum predicted air concentrations were extracted from the modeling results and used to estimate the bounding scenario risk from exposure through inhalation. The bounding off-site scenario was determined to involve a person located near the Site boundary inhaling the maximum predicted concentrations of air pollutants simultaneously on a long-term basis over a lifetime. This scenario is not likely to occur but represents the worst possible exposure to air pollutants near the Site.

Air was found to be the only pathway to potentially affect the off-site public. All other pathways (water, soil) were determined to be incomplete exposure pathways. The bounding scenario is for a 154-pound adult inhaling 20 m^3 of air per day, 365 days per year, for 30 years near the Site boundary where the highest air concentrations were predicted. Direct inhalation represents the maximum possible intake to the individual. Shorter term exposures or exposures to lower levels of chemicals or by different intake routes would equate to a lower risk to human health. These methods are consistent with EPA's *Risk Assessment Guidance for Superfund* (EPA 1989a). Details on the application of these methods are presented in Appendix B "Human Health and Safety."

For health effects other than cancer, the numerical estimate of risk is the *hazard quotient*, which, for the general public, is the ratio of the predicted intake from the Site to EPA's chemical-specific *reference dose*. This applies to chemicals that do not cause cancer but may impact public health. The non-cancer hazard quotient assumes that there is a level of exposure (reference dose) below which it is unlikely for even sensitive populations to experience adverse health effects. If the intake exceeds this threshold, there may be concern for potential non-cancer effects. However, the level of concern would not increase linearly as the threshold is reached or exceeded because these threshold values are not based on the same severity of toxic effects and effects would be chemical-specific.

For cancer-causing chemicals, the EPA chemical-specific *cancer slope factor* was multiplied by the predicted intake to estimate the individual's excess lifetime risk of cancer (the increase in probability of getting cancer). The calculation of cancer risk converts estimated daily intake averaged over a lifetime of exposure directly to incremental risk of an individual developing cancer. The slope factor assumes a linear dose response between intake and increased incidence of cancer. This means that the "true" risk would not exceed the risk estimated through use of a constant slope factor value and is likely to be lower than that predicted (EPA 1989a). The *National Contingency Plan* (EPA 1990b) guidelines for cancer risk are between an excess lifetime cancer risk of 1 in 1 million (10^{-6}) and an increase in cancer of 1 in 10,000 (10^{-4}). If risk from exposures are within this range, there may be some concern for cancer impacts. However, only risk orders of magnitude greater than 1 excess cancer in 10,000 would be unacceptable.

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5.9 Impacts on Ecological Resources

This section discusses the potential effects of the *baseline* and *closure* cases on ecological resources at the Site. Effects from the cases are summarized in this section.

Potential effects on ecological resources were semi-quantitatively assessed for seven resource categories: vegetation, wetlands, sensitive habitats, wildlife, aquatic fauna, species of special concern, and biodiversity (Section 5.9.7). The potentially affected resources are summarized here. Ecological resources currently found at the Site were identified and characterized in Section 4.9, "Ecological Resources".

The assessment of potential physical impacts is based on a comparison of the location of Site activities in relation to the location of ecological resources. Disturbances of various types (e.g., earthmoving, remediation, construction) would constitute the primary source of impacts such as loss of productivity, injury or mortality, and loss or modification of habitat.

The assessment of potential impacts from chemical contaminants was conducted by evaluating the potential for exposure of ecological resources to environmental contaminants.

Methods used in the impact assessment varied according to the type of impact and the ecological resource. Table 5.9-1 presents a summary of the impacts on ecological resources. Short-term impact ratings do not take reclamation measures or best management practices into account, which, if successful, would result in low (i.e., not substantial) long-term impacts.

Table 5.9-1. Summary of Impacts on Ecological Resources

Description	*Baseline Case*	*Closure Case*	Total Area (acres)
Vegetation			**6,449**
Short-Term Physical Impacts	Moderate	Low	–
Long-Term Physical Impacts	Moderate	Low	–
Chemical Impacts	Negligible/Low	Negligible/Low	–
Wetland and Riparian Habitat			**312**
Short-Term Physical Impacts	Moderate	High[1]	–
Long-Term Physical Impacts	Moderate	Low	–
Chemical Impacts	Negligible/Low	Negligible/Low	–
Sensitive Habitats			**5,069**
Short-Term Physical Impacts	Moderate	High[1]	–
Long-Term Physical Impacts	Moderate	Low	–
Chemical Impacts	Negligible/Low	Negligible/Low	–
Wildlife Habitat (affected area for key receptor species)			**6,449**
Short-Term Physical Impacts	Moderate	High[1]	–
Long-Term Physical Impacts	Low	Low	–
Chemical Impacts	Negligible/Low	Negligible/Low	–
Aquatic Fauna			**65**
Short-Term Physical Impacts	High	High[1, 2]	–
Long-Term Physical Impacts	Moderate	Moderate	–
Chemical Impacts	Low	Negligible	–
Habitat for Species of Special Concern			**5,333**
Short-Term Physical Impacts	High	High[1]	–
Long-Term Physical Impacts	Low	Low	–
Chemical Impacts	Negligible/Low	Negligible/Low	–
Biodiversity[3]			**6,449**
Short-Term Physical Impacts	High	Negligible	–
Long-Term Physical Impacts	Moderate	Negligible	–
Chemical Impacts	Low	Negligible	–

[1]High impacts are considered to be substantial.
[2]Assumes that no permanent open water is retained after remediation of pond sediments.
[3]Refers to the variety of plant and animal communities, and the species that make up those communities, within a geographical area (Section 5.9.7).

Under a Memorandum of Agreement (MOA) signed in 1996, a wetlands mitigation banking area is being developed to maintain wetlands functions and values in advance of wetlands disturbances resulting from Site operation and closure. The initial wetlands mitigation banking area for the Site is approximately 8.3 acres and is located next to the wetland mitigation area (12.9 acres) for the Standley Lake Protection project.

The consolidated compensatory wetlands is intended to provide enhanced wetland function and values for impacts to small, isolated fragmented wetlands that occur on site. Additional compensatory wetlands can be created as needed, under the existing MOA.

5.9.1 Impacts on Vegetation

Impacts on vegetation are considered substantial if any one of the following three conditions occurs: 1) there is a loss of greater than 10% of native plant species, 2) more than five years is required to reestablish ground cover to near pre-impact conditions, and/or 3) poisonous and/or noxious plants invade and occupy more than ten percent of a specific plant community where none existed prior to the impact.

Physical Impacts

Physical impacts associated with the *baseline* case would be limited to existing disturbance from facility operations and previous remedial actions. Implementation of this case would result in no further impact on Site vegetation. Existing impacts are weed infestation and build up of debris and thatch.

Under the *closure* case, upland habitat, including native grasslands, would be disturbed and subsequently revegetated using native species. However, this value represents less than 3% of the total area of native grassland at the Site and, therefore, is considered a low impact. Because the total disturbance area occurs within the Industrial Area, this acreage was not included as impacts on vegetation.

Because the majority of impacted areas occur in disturbed areas and reclaimed grasslands, impacts on vegetation for the *closure* case is low. Physical disturbance of non-native upland habitats under this case would ultimately result in positive impacts on the non-native and disturbed habitats because reclamation measures include using clean soil and native species. These communities are currently characterized by poor or severely disturbed soil, dominance of non-native species, and low diversity and productivity. Successful reclamation within five years would ameliorate these conditions and result in higher quality habitat than that existing in these areas.

Chemical Impacts

Based on preliminary exposure screening, potential for phytotoxicity (toxic effects on plants) due to Site activities is generally low or negligible under both *baseline* and *closure* cases. Data from broad-based ecological investigations also indicate negligible vegetation stress except, as described above, in areas that are physically disturbed.

5.9.2 Impacts on Wetlands and Riparian Habitats

Any violation of Executive Order 11990 (protection of wetlands), loss of wetland and/or riparian habitat at any location in excess of one acre, or the combined loss of more than ten acres of wetland and/or riparian habitat is considered a substantial impact.

Physical Impacts

Impacts from physical stress on wetlands and riparian areas under the *baseline* case would be limited to existing conditions. Tall marsh is most affected by physical stress under this case because it is most commonly associated with pond margins, ditches, and stream segments where irregular flows and fluctuating water levels of the existing pond water management scheme can stress wetland vegetation. Implementation of the *baseline* case would result in no additional impact on Site wetlands. Existing impacts under the *baseline* case are due to reduced flows below terminal ponds, maintenance activities and responses to potential spills/releases of contaminants.

Disturbance of wetland and riparian areas associated with the *closure* case would result in the loss of approximately 14 acres of these communities in one location and, therefore, is considered a substantial impact. This disturbance amounts to less than 4% of the total wetland and riparian habitat at the Site. Appropriate reclamation would hasten the recovery of these habitats. In addition, reduced flows in North and South Walnut Creek drainages would probably reduce the area of wetland and aquatic habitats (see Section 5.4.4, "Impacts on Local Hydrogeology").

Although substantial impacts on wetland and riparian resources result from implementation of the *closure* case successful wetland enhancement, restoration, or creation, as required by U.S. Army Corps of Engineers wetland regulations, would result in low impacts during the long term.

Chemical Impacts

Chemical impacts on wetland vegetation under the *baseline* case is limited to metals in pond and stream sediments in the OU7 landfill pond and A-, B-, and C-series ponds. A preliminary risk screen indicates that silver levels in the B-series pond sediments may represent a moderate to high level of toxicity to plants. However, this risk may be overstated, as these ponds currently support tall marsh communities along their margins. Levels of other metals in these sediments represent a low risk to wetland and riparian vegetation. Contaminants potentially released by spills could create impacts under *baseline* case.

All pond sediments would be remediated under the *closure* case, thereby reducing the exposure risk to wetland and riparian vegetation. Some residual, low risk may remain following remediation if the streams reaching between the ponds are not remediated as well.

5.9.3 Impacts on Sensitive Habitats

Impacts on sensitive habitats are considered substantial if any threatened, endangered, or sensitive wildlife species are affected and/or if more than 1% of the sensitive habitat available is disturbed.

Five categories of sensitive habitats were identified at the Site (Section 4.10.3): native grasslands, wetlands, riparian areas, foothills shrublands, and ponderosa pine woodlands. Native grasslands on-site consist of mesic mixed grassland, xeric mixed grassland, and short grassland.

Physical Impacts

Physical impacts associated with the *baseline* case would be limited to existing disturbance resulting from facility operations and previous remedial actions. Implementation of this case would result in no additional impacts on sensitive habitats. However, current water management practices (batch-release) limit flows, below terminal ponds and may allow population of natural flows. Physical disturbances during spill responses may have a substantial impact.

Implementation of the *closure* case would disturb mesic mixed grassland, and xeric mixed grassland. Although the affected acreage represents only a small portion of native mixed grasslands, the impacts could be considered substantial. The third native grassland community—short grassland—would be unaffected under the *closure* case.

Fourteen acres (4%) of these habitats would be subject to physical impacts under the *closure* case and, therefore, is considered to be a substantial impact. Additional impacts on wetlands under this case would include a reduction in open-water habitat and increases in other wetland types.

Activities under the *closure* case would also result in physical impacts on riparian woodland habitat. Unlike other wetland habitats at the Site, riparian woodlands are dominated by mature willow and cottonwood trees. This habitat would take decades to recover its full ecological significance if these trees were killed or removed. Therefore, these would be considered substantial impacts.

Of the two plant communities included in the foothills shrubland habitat, tall upland shrubland cases and one acre of short upland shrubland would not be subject to physical impacts under either

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of the cases. None of the ponderosa pine type habitat would be physically disturbed be either the *baseline* or *closure* case.

In summary, substantial short-term impacts on sensitive habitats would occur under the *closure* case. However, planning Site activities to avoid and/or minimize disturbance to sensitive habitats (through best management practices) would result in low long-term impacts.

Chemical Impacts

Foothills shrubland and ponderosa pine woodland habitats would not be adversely affected by chemical stress under either of the *baseline* or *closure* cases because of their location in the western and northwestern portions of the Site. Because risk values for contaminant concentrations in soils or sediments are low and native plant communities within the source areas do not appear to have been adversely affected, impacts from chemical stress to native grassland habitats and to wetland and riparian habitats are considered negligible.

Some short-term chemical stress could result from mobilization of contaminants to sensitive habitats located near remediation sites. However, best construction management practices are expected to prevent this impact.

5.9.4 Impacts on Wildlife

Impacts on terrestrial species and habitats are considered substantial if any threatened, endangered, or sensitive wildlife species are affected and/or if more than one percent of the sensitive habitat available is disturbed.

Existing and potential site activities that could result in disturbances to wildlife include loss or change of habitat from construction of new facilities and/or remediation activities; mortality from land clearing or facility removal operations; mortality from vehicular traffic; human presence; noise; night lights; and exposure to radionuclides and hazardous contaminants or waste. A potential beneficial effect would be revegetation of disturbed areas once remediation and maintenance activities are completed.

The potential affects of physical and chemical impacts are summarized below.

Physical Impacts

Existing areas of physical disturbance that would continue under the *baseline* case consist of those affected by prior agriculture, facility operations, and current remedial actions. Current pond water management represents an additional source of physical stress on some species because of widely and rapidly fluctuating water levels in some of the ponds and intermittent flows in most stream segments. Implementation of this alternative would result in no additional impacts on wildlife.

Site operations under the *closure* case would result in habitat disturbance to acres of key receptor species habitat. This is considered a substantial short-term impact. However, the *closure* case includes plans to reclaim affected areas and revegetate them with native species within the timeframe of the *closure* case. Under the *closure* case, a large proportion of the areas that would be disturbed and reclaimed are currently developed and non-native communities. Reclamation of these sites would actually benefit local wildlife in the long term. Implementation of this case would result in the permanent loss of open-water habitat. Remediation under the *closure* case would reduce some of the stress associated with the current surface-water management program and offset open-water habitat loss with an increase in wetland habitats.

Assuming successful reclamation, disturbance to these habitats would be short-term impacts. However, pockets of habitat throughout the Site would be disturbed concurrently, thus fragmenting possible refuge areas for wildlife. In addition, access to nearby off-site habitat, which is limited, would be further constrained by activities occurring under the *closure* case. As a result,

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species that depend on habitat types disturbed by Site activities may have difficulty locating appropriate refuge during recovery of on-Site habitat. This may reduce the size of resident populations and affect the re-establishment of individuals and species following reclamation.

Chemical Impacts

Screening-level risk characterizations indicate that ecological components (e.g., vegetation, soils) in several source areas contain contaminants at levels that represent low or negligible risk to wildlife.

5.9.5 Impacts on Aquatic Fauna

Impacts on aquatic fauna are considered substantial if Site activities disturb more than 10% of the available aquatic habitat.

The Site contains approximately 24 acres of lentic (standing-water) habitats (A-, B-, and C-series detention ponds) and 41 acres of ponds, streams, and ditches representing less than 1% of the total area of the Site. The combination of low and intermittent surface flows in streams and ditches and fluctuating water levels in the detention ponds substantially reduces the quality of these habitats.

Physical Impacts

The *baseline* case utilizes the present "batch discharge" system (Section 4.4.3, "Surface Water Characteristics") of pond water management, which results in widely and rapidly fluctuating water levels, particularly in the three terminal ponds (A-4, B-5, and C-2). Implementation of this case would result in continuation of the current adverse impacts, but no additional impacts, on the terminal ponds and downstream stream reaches. These impacts include physical stress to aquatic biota, periodic loss of individuals or entire communities, and extremes in water physicochemical characteristics (especially dissolved oxygen, temperature, pH, and turbidity). These impacts would greatly limit the ability of the affected sites to support natural, diverse, and self-sustaining aquatic communities.

Under the *closure* case, a flow-through water management system would be implemented. This would include elimination of the Site ponds and conversion to wetlands. Open-water habitat would be reduced by. Aquatic fauna in these areas would be washed downstream or die from desiccation. However, change to a flow-through water management system will provide more sustained flows to allow additional habitat downstream of the terminal ponds. Because reclamation plans for these areas do not include areas of standing water, this represents a permanent loss of aquatic habitat at the Site and, therefore, is considered a substantial short-term impact. Some losses would be offset by establishment of new wetland habitats resulting in moderate long-term impacts.

Chemical Impacts

Ecological risk assessments and standard laboratory tests indicated little or no exposure of aquatic fauna to chemical impacts.

5.9.6 Impacts on Species of Special Concern

Impacts on species of special concern are considered substantial if any threatened, endangered, or sensitive plant or animal species are adversely affected and/or if more than 1% of the sensitive habitat available is disturbed.

Species of special concern for the Site are as follows:

- Mammals–Preble's meadow jumping mouse, black-footed ferret, and swift fox.

- Birds–bald eagle, peregrine falcon, northern goshawk, ferruginous hawk, loggerhead shrike, long-billed curlew, American white pelican, burrowing owl, Baird's sparrow, and mountain plover.
- Invertebrates–regal fritillary (butterfly).
- Plants–forktip three-awn, Ute ladies-tresses, Colorado butterfly plant, toothcup, gay feather, and yellow stargrass.

Physical Impacts

Native grasslands are the most important habitats on-site in terms of species of special concern because they are the preferred habitat for eight of the 13 vertebrates, the one invertebrate (the regal fritillary butterfly), and one of the six plants (yellow stargrass) that have been observed or are potentially present. Other affected habitats that potentially support species of special concern include reclaimed grassland, riparian woodland, and open-water. Implementation of the *baseline* case would not disturb the following areas supporting or potentially supporting species of special concern. However, the *closure* case once implemented, would disturb areas supporting or potentially supporting species of special concern. The disturbance could represent a substantial physical impact for most habitats of species of special concern. However, this impact may be overstated because of their irregular occurrence (or lack of documented occurrence), in some cases the small loss of suitable habitat on-site, and availability of comparable habitat elsewhere. Exceptions to this generalization are the moderate long-term impacts due to the permanent loss of open-water habitat under the *closure* case. The disturbances would be partially offset by changing to a flow-through water management system. The *closure* case will provide more sustained flows to sensitive habitats downstream of the terminal ponds.

Assuming implementation of best management practices to avoid and/or minimize impacts to these acres and successful reclamation, disturbance of these habitats would be low in the long term. However, disturbance and fragmentation of suitable habitat off-site could limit the ability of wildlife to successfully relocate or shift home ranges during recovery of habitat at the Site. This may reduce populations or cause individuals to leave the area, therefore limiting the number of individuals and species available to re-establish populations at the Site following reclamation.

Chemical Impacts

Existing conditions do not appear to represent a substantial risk of adverse affects from chemical impacts because of the low frequency, duration, and intensity of use of the Site by most of the species of special concern.

The only plant species of special concern that has been documented at the Site (forktip three-awn) is not subject to chemical impacts because the occupied locations are not in areas that would pose a risk of phytotoxicity from contaminants in soils.

5.9.7 Impacts on Biodiversity

The term "biodiversity" refers to the variety of plant and animal communities, and the species that make up those communities, within a geographical area. Historically, the term has been applied primarily at the regional, continental, or global scale. Within the past few years, biodiversity has become a generalized indicator of overall ecological health and has been increasingly applied at a more localized level. In the context of these cases, biodiversity combines the variety of communities and the number of individual species and connotes the contribution of the local biota to the larger scale region in which the local area is situated.

The Buffer Zone, which is one of the largest tracts of undeveloped land in the Denver Metropolitan Area, has been protected from agriculture (including grazing and dryland wheat production) for several decades as well as from the development pressures experienced in much of the surrounding region. Consequently, the Site supports a number of habitats that have either been

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substantially reduced in much of the region or are in better condition on-site because of protection from disturbance. Therefore, degradation of native communities on-site by physical disturbance or exposure to environmental contaminants could adversely affect not only the Site but also regional biodiversity.

Assessment of impacts on biodiversity consisted of qualitatively evaluating potential adverse effects on relatively rare communities or on populations of relatively rare plant and animal species at the Site. Impacts on rare communities could range from shifts in composition or dominance to (at an extreme) complete elimination. Potential impacts on populations of rare species include reduction in total numbers or elimination from parts or all of the Site as a result of direct mortality or a reduction in critical habitat to a level that cannot sustain a viable population.

Much of the information described in this section has already been presented in sections addressing upland vegetation, wetland and riparian vegetation, sensitive habitats, wildlife, and species of special concern. This section differs from those by focusing on potential impacts on the biodiversity of local and regional ecosystems rather than on impacts on habitat quality or the well being of individual species.

Physical Impacts

Cumulative impacts on regional biodiversity would occur as a result of any development in the area. Past history has shown that wildlife populations undergo change as a result of the presence of human activity. Habitats are altered, water regimes are changed, and plant species undergo population and distribution shifts. The *baseline* and *closure* cases would require some kind of human activity. The impacts of these cases in conjunction with the development of off-site residential and commercial activities would result in alteration or loss of habitat.

Effects of physical stress on biodiversity resulting from implementation of the *baseline* case would consist of those effects that already exist. These include areas that have previously been disturbed by facility operation, previous remediation activities, prior agriculture, and the current pond water management system. The *baseline* case would have some impact on regional biodiversity. The impacts would be primarily due to maintenance activities and reduced flow below terminal ponds. Reclamation measures can be utilized to minimize the potential impacts from maintenance activities.

Under the *closure* case, reduction of open-water habitat would result in lower diversity of aquatic species on-site. However, in a regional context, given the low habitat quality and relatively small area affected, it is considered to be a negligible impact on biodiversity. If reclamation restores wetland structural diversity, wetland species diversity would increase and may eventually return the overall biodiversity to current levels during the long term.

Chemical Impacts

Existing ecological risks from chemical contaminants would continue under the *baseline* case. Site activities under the *closure* case would reduce the area of contamination to varying extents. However, because existing contamination levels do not appear to have substantial adverse effects on biota, the *closure* case would not be expected to increase biodiversity of the Site or region.

Potential impacts from short-term chemical stress during remediation would be minimal with regard to biodiversity and would be prevented or minimized by reclamation measures.

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5.10 Impacts on Cultural Resources

Impacts on cultural resources are considered substantial if the action results in : 1) the loss or modification of cultural resources eligible for the National Register of Historic Places, 2) the failure to comply with state procedures implementing cultural resource management practices, or 3) the loss of any information that impedes efforts to reconstruct the prehistory or history of the region.

Future undertakings by DOE may create adverse effects on historical resources at the Site through any changes in the characteristics that qualify the property to meet the eligibility criteria of the National Register of Historic Places. Historical resources identified as eligible for the National Register of Historic Places at the Site consist of 49 buildings directly associated with the central mission of the plant and 15 secondarily associated facilities. These 64 facilities are eligible as an historic district. Eligible cultural resources at the Site and the applicable laws and regulations pertaining to them are listed in The Rocky Flats Cultural Resource Management Plan (DOE 1997). Cultural resources potentially affected under each case are summarized in Table 5.10-1.

Table 5.10-1. Cultural Resources Potentially Affected Under Both Cases

Program/Item	*Baseline Case*	*Closure Case*
Facility DD&D	None from deactivation or activities involving non-historic facilities	Adverse effects to all historic facilities as a result of decontamination, decommissioning, and removal
Waste Treatment	None	Modifications to Buildings 371, 774 and new construction may cause adverse effects
Waste Storage	None	Adverse effects caused by Conversion of Buildings 440, 881, 991 and others for waste storage
Waste Transportation/Disposal	None	None

In 1995, a *Cultural Resources Survey* report was prepared for DOE (DOE 1995x). Cultural resource management recommendations for the 64 eligible resources were included in the report. The following potential activities that would constitute substantial impacts to the historic resources were identified:

1. Demolition of historic buildings or structures,
2. Relocation of buildings to an off-site location if it is important in defining the historic character and context of the Site, and/or
3. Alterations that obscure, damage, or destroy historic material or distinctive architectural features.

The report recommends the selection of appropriate measures that would reduce impacts to non-adverse levels, in consultation with the State Historic Preservation Officer, if any future projects would adversely affect the historic properties identified at the Site. These measures may include avoidance, preservation in place, rehabilitation, or data recovery. If data recovery is chosen, it is likely that Historic American Building Survey or Historic American Engineering Record documentation would be prepared prior to the implementation of any activity that could affect the character or integrity of the property.

Historical resources in the Buffer Zone are not considered significant to the region's historic record by the State Historical Preservation Officer. No historic, archaeological, or architectural sites in the Buffer Zone are eligible for the National Register of Historic Places according to the

State Historic Preservation Officer. Therefore, undertakings in the Buffer Zone would not result in any adverse effects on historical resources.

Currently, DOE is consulting with the Colorado State Historic Preservation Officer (SHPO) with regard to buildings and structures eligible for inclusion on the National Register of Historic Places (National Register). No buildings or structures at RFETS have been designated at this time to be a National Historic Landmark, however, a number of facilities have been identified as being eligible for inclusion on the National Register. As a result of this eligibility, DOE will consult with the SHPO regarding appropriate mitigation measures. In the event of unanticipated discoveries of cultural resources during excavation or ground disturbing activities the Colorado SHPO will be notified immediately. In addition, each undertaking to be conducted under the RFCA will be reviewed to determine its potential to have significant adverse impact on historic and cultural resources.

Paleontological Resources

Given that rock exposures at the Site are not fossil-bearing, it is unlikely that remediation activities would uncover paleontological resources. Undertakings at the Site are unlikely to result in the deterioration or loss of any substantial paleontological resources.

Prehistoric Resources

Prehistoric resources at the Site are not considered substantial to the region's archaeological record. Therefore, undertakings at the Site would be unlikely to result in the deterioration or loss of prehistoric resources, and mitigation would be recommended only in the event that new prehistoric/archaeological remains are uncovered during construction or remedial activities. Procedures for emergency treatment of archeological resources in the Buffer Zone are addressed in the Site Cultural Resources Management Plan.

Native American Concerns

Cultural resources associated with the traditional use of the Site by Native American cultures have not been identified; therefore, impacts are not quantifiable and are expected to be negligible.

5.11 Impacts on Noise Levels

The noise impact assessment evaluated the effects of the *baseline* and *closure* case on public and worker noise levels. The methodology used to assess noise impacts, the impacts on public noise levels, and impacts on worker noise levels are presented below.

5.11.1 Methodology

The predominant sources of noise that affect both public and worker noise levels occur within the Site. Off-site activities such as waste transport and worker commuter trips affect the public noise levels for surrounding residential land uses. Typical examples of on-site and off-site noise-generating activities that would occur under the *baseline* and *closure* case are shown in Table 5.11-1.

Table 5.11-1. Noise Generating Activities by *Baseline* and *Closure Case*

Activity	*Baseline Case*	*Closure Case*
Work force	6,977 employees	3,575 employees
Transport of Waste (off-site trips per year)	102	774
Landfill of Sanitary Waste (trips per year)	1,037 (on-site)	1,231 (on-site or off-site)
Environmental Restoration Activities	Minimal activity	RCRA monitored retrievable storage in the Industrial Area; soil remediation
Environmental Restoration Waste and Fill (trips per year)	Minimal activity	19,173
Demolition of Facilities	None	700+ buildings and structures

Noise levels associated with common sources are presented in Table 5.11-2.

Table 5.11-2. Noise Levels Associated with Common Sources

Source/Physical Sensation	Noise Level (dBA)
Threshold of Audibility	0-10
Whispering	20-30
Conversation	60-70
Telephone Bell	70-80
Vacuum Cleaner	80-90
Circular Saw	100-110
Amplified Rock Band	120-130
Threshold of Pain	140-150

Noise levels for equipment which could be used for the construction and demolition of buildings are presented in Table 5.11-3 (CERL 1979). The noise levels presented are at a reference distance of 50 feet. The construction equipment noise levels decrease at a rate of approximately 6 dBA per doubling of the distance. Therefore, at 100 feet the noise levels would be about 6 dBA less than the levels shown at 50 feet. Similarly, at 200 feet the noise levels would be 12 dBA less than shown. Intervening structures or topography can act as a noise barrier and reduce noise levels further. Over very large distances of 1 mile or more, additional sound attenuation occurs due to atmospheric conditions of temperature, humidity, and wind speed and direction.

Table 5.11-3. Noise Levels Associated with Various Types of Equipment

Equipment Type	Sound Level at 50 feet dBA
50-250 ton Crane	90
Backhoe	85
D7, D8, and D9 Bulldozers, Compactors	89
Fuel and Lubrication Trucks	88
Water Truck	88
Motor Grader	85
Vibrator/Roller	80
Dump Truck	88
Commercial Tractor	80
Concrete Truck	74
Front End Loader	83
Air Compressor	82
Automobile, Pickup Truck	80

Estimated construction noise levels are presented in Table 5.11-4 at each of the six receptor sites where ambient noise levels were measured (see Section 4.12, "Noise"). Construction, environmental restoration, waste disposal or retrievable, monitored storage, and demolition activities are expected to occur under the *closure* case. The main environmental restoration activity that is expected to generate noise is soil remediation. Noise levels from on-site construction, environmental restoration, waste disposal or retrievable, monitored storage, and demolition activities are not expected to be perceptible at any of the six locations.

Table 5.11-4. Estimated Noise Levels from Construction and Demolition Activities

Site	Location	Ambient Noise Level (dBA)	Construction Noise Level (dBA)
1	Equinox Equestrian Center	46 dBA	35 to 39 dBA
2	Residential property at Alkire Street	41 dBA	33 to 38 dBA
3	Open space area along Indiana Street	57 dBA	35 to 40 dBA
4	New residential development along McCaslin Blvd.	40 dBA	32 to 37 dBA
5	Open space area along Colorado State Highway 128	39 dBA	35 to 40 dBA
6	Residential area along Colorado State Highway 93	61 dBA	35 to 40 dBA

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The evaluation of potential impacts was qualitatively assessed by comparing the proposed activities for the *closure* case to *baseline* noise conditions as described in Section 4.12, "Noise."

5.11.2 Impacts on Public Noise Levels

Potential effects on public noise levels would be generated by both on-site and off-site activities. The on-site activities consist of manufacturing and industrial operations, chemical processing, environmental restoration activities, and construction/demolition activities. Off-site activities consist of waste transport from the Site, material delivery, and daily employee trips.

For the *closure* case, 700+ buildings and structures would be demolished and buildings for storage of SNM and TRU waste shipping and staging facility would be constructed. These activities would be a source of increased on-site noise levels. However due to the long distances between the Industrial Area of the Site and the surrounding land uses, the resulting noise levels are expected to be the same as or lower than the ambient noise levels (see Table 5.11-4). All of the waste would be shipped off-site, with an average of 774 trips per year for off-site transport of waste. Solid sanitary waste would be landfilled either on-site or off-site, with an average of 1,231 trips per year. The total number of on-site workers would be 3,575 in an averaged year (over a ten year period), resulting in a decrease in traffic noise levels to off-site residential uses located along State Highway 93, the closest state route to the Site.

Environmental Restoration would result in higher public noise levels due to approximately 19,173 trips for fill and waste transport. On-site transport of waste and demolition activities would result in increased on-site noise levels. However, given the distances between these activities and adjoining residential areas, an increase in public noise levels is not expected to be noticeable. The predominant impact to public noise level occurs when the number of trips to and from the Site is increased.

5.11.3 Impacts on Worker Noise Levels

Potential effects on worker noise levels would result from both on-site and off-site activities. On-site activities consist of manufacturing and industrial operations, chemical processing, and construction/demolition activities. Off-site activities consist of waste transport from the Site, material delivery, and daily employee trips.

For the *closure* case, remediation and construction of new facilities would generate more on-site activities, which may result in higher worker noise levels. However, the overall impact is considered low.

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5.12 Impacts on Socioeconomics

In terms of socioeconomics, the Site has a complex set of influences on the Denver Metropolitan Area and Colorado economies. The primary socioeconomic factors considered in this analysis are employment, local economy, population and housing, and quality of life. These factors were selected because they are general indicators of economic conditions, are measurable and commonly understood, and can be compared to available information on the state and local economies. The analysis covered the six-county Denver Metropolitan Area and the remainder of the state. Out-of-state impacts were not addressed.

Changes in socioeconomic indicators are considered substantial if the case results in a change of 10% or more in any of the socioeconomic factors considered. Tables 5.12-1 and 5.12-2 summarize the changes in socioeconomic indicators of the *closure* case as compared to the *baseline* case.

Table 5.12-1. Changes in Socioeconomic Indicators in the Colorado Economy in the Next Ten Years as Compared to the *Baseline and Closure Cases*

Socioeconomic Indicator	***Baseline Case***	***Closure Case***
Employment (Direct and Indirect)	16,500	**(15,600)**
Payroll	$688,459,477	**($652,343,223)**
Site Purchases	$1,349,585,229	**($1,281,047,669)**
Nonresidential Space Demand (square feet)	3,726,802	**(3,553,790)**
Housing Demand	11,809	**(11,167)**
Quality of Life (measured in terms of change in public perception)	No change	Positive change

Note: All changes in bold reflect a change of 10% or more and are considered to be substantial. Figures in parentheses indicate a decrease.

Table 5.12-2. Changes in Socioeconomic Indicators in the Denver Metropolitan Area Economy in the Next Ten Years as Compared to the *Baseline Case*

Socioeconomic Indicators	***Baseline Case***	***Closure Case***
Employment (Direct and Indirect)	15,782	**(14,929)**
Payroll	$658,237,225	**($623,958,840)**
Site Purchases	$1,292,882,821	**($1,227,726,563)**
Nonresidential Space Demand (square feet)	3,571,100	**(3,406,559)**
Housing Demand	11,273	**(10,644)**
Quality of Life (measured in terms of change in public perception)	No change	Positive change

Note: All changes in bold reflect a change of 10% or more and are considered to be substantial. Figures in parentheses indicate a decrease.

The changes identified above, however, must be put into the context of what else is projected to happen in the state and in the Denver Metropolitan Area economies by the year 2006. Some of these anticipated conditions, summarized below, utilized projections from the State of Colorado and the Denver Regional Council of Governments. It should be noted that the Denver Metropolitan Area projections developed by the Denver Regional Council of Governments include an assumed reduction of 4,000 Site-related jobs.

- The State of Colorado's population is projected to increase 18.3% from 1994 to 2006, at an average annual rate of 1.4%. For the same period, a separate study projects Colorado's employment to increase by approximately 28.6%, at an average annual rate of 2.1%.
- Population in the Denver Metropolitan Area is projected to increase by 15.3% from 1994 to 2006, at an average annual rate of 1.2%, while the area's employment is projected to increase by approximately 17.5% during those years, or 1.4% annually. During the same period, the number of households in the Denver Metropolitan Area is expected to increase by approximately 18.8%, or 1.4% annually.
- Populations in Boulder and Jefferson Counties are projected to increase respectively by 15.2% (1.1% annually) and 11.6% (0.8% annually) from 1994 to 2006.
- Of the major work sectors—production, retail, and services—the Denver Metropolitan Area's services sector is projected to be the largest and grow the most from 1994 to 2006. The services sector is anticipated to increase by 24.1% during this timeframe, at an average annual rate of 1.8%.
- While the loss of 15,634 jobs under the *closure* case is a substantial decrease, it represents only 1.2% of the projected employment for the Denver Metropolitan Area in the year 2006.

The socioeconomic indicators for activities under the *closure* case decrease over time as compared to activities under the *baseline* case due to decreases in the levels of employment and spending at the Site. This decrease would be substantial as a result of the completion of Site stabilization and closure activities. These decreases in economic activity would be counterbalanced against a local economy, which is forecasted to grow. The growing local economy would facilitate job transition for those who lose jobs as a result of reductions in Site activity and lessen the impact on businesses that sell goods and services to the Site or its vendors. Although activities under the *closure* case would result in substantial decreases in socioeconomic indicators, these changes would be counterbalanced by the projected growth of the local economy. Activities under the *closure* case, therefore, are not expected to result in any substantial socioeconomic impacts to the Denver Metropolitan Area and Colorado.

Methodology

A combination of quantitative economic and financial models, such as input-output models, and qualitative descriptions of socioeconomic impacts were used in the socioeconomic analysis. An input-output model measures the direct and indirect impacts that activities have on the economy. The primary analytical tools, methods, and results are summarized below.

Direct economic impacts are expenditures of labor (payroll), products, and services (purchases) by DOE, the Site contractor, the protective force, subcontractors, and vendors operating at the Site. Examples are salaries paid to scientists who work at the Site, purchases of office supplies made by the plant manager, and vendor services provided by consulting engineering firms who are retained by the Site contractor. Indirect economic impacts are additional rounds of consumer and business transactions triggered by initial Site expenditures. These transactions are made by employees of the Site and the vendors who in turn also purchase goods and services. Examples include computer equipment purchased by a consulting engineering firm (vendor), grocery purchases made

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by the Site contractor and consulting engineering firm employees, and teacher salaries to educate the children of the employees.

Operations at the Site were classified depending on whether the operation was performed by DOE, the Site contractor, or its protective force.

Micro IMPLAN input-output models were the primary tools used in the *baseline* case and *closure* case measuring the indirect economic impacts of each case on the metropolitan area and state economies.

Direct Site employment, payroll, and purchases were entered into the model, which then calculates direct and indirect economic impacts in terms of employment, payroll, and purchases for the peak year[1], when Site activity and employment levels would be highest, and for 2006.

The input-output model was calibrated using economic conditions that prevailed in the local economy in 1994. To clearly isolate the impacts of the Site cases from any other activity in the local economy, the impacts are described as if they are the only change in local economic conditions or as if the remainder of the local economy remains constant. To provide perspective, the magnitude of the impact is also compared with figures for the state and the metropolitan area, as appropriate.

The analysis of employment was based on detailed information regarding salaries and county of residence of the (direct) Site work force. The analysis of purchases of goods and services was based on detailed information regarding purchases by type and vendor in 1994. The distribution of vendor locations was assumed to remain consistent for the cases while the volume of purchases by vendor was assumed to change.

Quality of life indicators were compiled through an investigation of quality of life issues identified in prior scoping and public work sessions and supplemented by independent research. This section of the CID focuses only on quality of life indicators that do not relate to human health issues or environmental justice; human and health related issues are addressed above in Section 5.8, "Impacts on Human Health and Safety," and environmental justice issues are addressed below in Section 5.13, "Impacts on Environmental Justice."

The four primary types of socioeconomic indicators used in the *baseline* case and *closure* case (employment, local economy, population and housing, and quality of life) were introduced in Chapter 4, "Affected Environment." The discussion of employment includes an analysis of the number of jobs, and the payroll generated. The discussion of the local economy includes an analysis of the purchases of goods and services and the amount of private-sector nonresidential space occupied by businesses providing goods and services. The discussion of population and housing provides estimates of changes in housing demands. The discussion of quality of life includes general consideration of issues such as crime, air quality, growth management, and public perception of environmental stigma.

5.12.1 Forecasted Conditions

The Colorado State Demographer and the Denver Regional Council of Governments have forecasted future rates of growth at a solid but somewhat slower pace than experienced in the 1970s and early 1980s. This forecast accounts for factors such as the completion of Denver International Airport construction, closure of Lowry Air Force Base, downsizing of major employers such as Continental Airlines and Public Service Company, and an anticipated slowing migration. Sectors experiencing the strongest rates of growth are anticipated to include wholesale and retail trade, finance, insurance, real estate, and services. Slow growth is expected in construction, government, manufacturing, transportation, communications, and public utilities.

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[1] *"Peak year" represents the year during which the specific economic activity(ies) being discussed reaches its highest level under that case, within the 10-year CID timeframe. Thus, the "peak year" may vary from activity to activity, and from case to case.*

In March 1995, the Denver Regional Council of Governments prepared population, household, and employment forecasts for the Denver Metropolitan Area in the year 2020 (DRCOG 1995b). The council also prepared several alternative allocations of population, households, and employment which are currently under consideration. The *baseline* case and *closure* case analysis used the allocation most consistent with a continuation of current trends. In August 1995, the State Demographer's Office and the Colorado Department of Local Government prepared population forecasts through the year 2020 (CSDO 1995). In March 1995, the Colorado Department of Labor and Employment prepared forecasts of employment through 1999 (CDLE 1995a).

The following discussion provides population and employment forecasts for 2006, the year for which the *closure* case was analyzed. Where available, forecasts are also provided for the year 2020. In all cases, it was necessary to interpolate the data to provide consistent information for the year 2006.

The State Demographer forecasts that population in the State of Colorado will increase at an average annual rate of 1.4% between 1994 and 2006. The Denver Regional Council of Governments forecasts population growth in the Denver Metropolitan Area to experience an average annual increase of 1.2% per year between 1994 and 2006. The metropolitan area is forecasted to capture 50% of state growth (Table 5.12-3).

Table 5.12-3. Forecasted Population: State of Colorado and Six-County Denver Metropolitan Area

Area	1994	2006	2020	Average Annual Percent Change (1994-2006)
Colorado	3,665,647	4,337,164	5,049,000	1.4
Denver Metropolitan Area	2,012,300	2,320,615	2,744,529	1.2

The Colorado Department of Labor and Employment forecasts employment to increase at an average annual rate of 2.1% per year between 1994 and 2006. The Denver Regional Council of Governments forecasts employment to increase at a rate of 1.4% per year between 1994 and 2006. The council's employment forecasts were based on assumptions that the U.S. population will continue to increase while employment and labor force participation will decline slightly after 2010 as the population ages. The Denver Regional Council of Governments assumes that the Site's work force will be reduced by 4,000 jobs (DRCOG 1995b, CDLE 1995b) (Table 5.12-4).

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Table 5.12-4. Forecasted Employment by Place of Work: State of Colorado and Six-County Denver Metropolitan Area

Area	1994	2006	2020	Average Annual Percent Change (1994-2006)
Colorado[1]	1,722,100	2,213,827	N/A	2.1
Denver Metropolitan Area	1,072,312	1,260,057	1,527,160	1.4

[1]Colorado figures exclude agriculture.

The Denver Regional Council of Governments anticipates that production employment will increase primarily as a result of growth from the opening of Denver International Airport and continuing technological advances in communications. Wholesale trade will experience some growth due to the region's larger population base and its function as a distribution center for the Rocky Mountain region. Retail trade will increase more modestly, and the services sector is expected to represent more than 70% of job growth. Health services and business services are expected to experience particularly strong increases (Table 5.12-5).

Table 5.12-5. Forecasted Employment by Place of Work by Sector: 1994, 2006, and 2020–Six-County Denver Metropolitan Area

Type	1994	2006	2020	Average Annual Percent Change (1994-2006)
Production	268,852	296,591	332,591	0.8
Retail	261,347	290,908	329,648	0.9
Services	542,113	672,558	864,921	1.8
Total	1,072,312	1,260,057	1,527,160	1.4

Notes: Production = SIC Codes 01-51; Retail = SIC codes 52-59; Services = SIC Codes 60-99; Employment figures exclude self-employed and sole proprietors. Figures for 2020 adjusted to add agriculture (DRCOG 1992 and 1995b).

Forecasts of population and employment by county within the metropolitan area have been compiled by the Denver Regional Council of Governments. Within the Denver Metropolitan Area, Adams County and Douglas County are anticipated to attract the largest increases in population for the forecasted study period. Adams County's residential growth is attributable to the attraction of Denver International Airport; Douglas County's residential growth is attributable to its location at the margin of existing suburban growth and its strategic position relative to services employment along the Interstate-25 corridor. Denver's population is expected to remain relatively flat. Population in Jefferson County is expected to increase at a lower rate than that of the metropolitan area (0.8% versus 2.1% over the forecasted period).

The most notable forecasted increases in metropolitan area employment are anticipated in Arapahoe and Adams Counties. In Arapahoe County, the forecasted increase is due to the presence of large office parks along the Interstate-25 corridor, and in Adams County, the forecasted increase is due to the presence of Denver International Airport. With the anticipated reduction in Site-related jobs, Jefferson County employment is forecasted to increase at an average annual rate of 0.9% per year.

5.12.2 Impacts on Employment

Three types of employment were estimated in this analysis: 1) Site employment, which includes those employed by the Site contractor and DOE; 2) other direct employment, which includes employees of vendors hired by the Site contractor and DOE; and 3) indirect employment, which includes employees hired as a result of spending effects from Site employees and its vendors.

Economic impacts from changes in employment would be influenced by several factors, including the absolute number of jobs lost or gained by employment category, general strength of the local economy, demand for different types of jobs over the study period, and differences in salary and wage levels of Site-supported jobs relative to potential replacement jobs.

Activities under the *closure* case result in a decrease in Site workforce over time as compared to activities under the *baseline* case. Two studies of the re-employability of workers who would lose Site jobs have been completed within the last few years. The most recent study (EG&G 1995e) found that much of the Site work force is experienced and well educated and may be able to re-enter the labor market with relative ease. The second study (RFLII 1994b) concluded that the displaced workers have skills that are attractive to other potential employers and that many of those occupations experiencing reductions at the Site are forecasted to be in demand in the Denver Metropolitan Area. This study also reported that the salary and benefits packages in new positions might not be commensurate with total compensation packages at the Site.

The average salary (in 1996 dollars) by job classification for on-site workers employed by the Site contractor are listed in Table 4.13-8 in Chapter 4. The average salary for all off-site jobs is generally $12,000 below the average salary of on-site jobs because the mix of off-site jobs includes a high proportion of jobs in lower paying industries such as retail trade.

The decreases in Site workforce from activities under the *closure* case would result in subsequent decreases in employment in Colorado. Activities under the *closure* case would result in substantial decreases in Colorado employment, with a decrease from activities under the *baseline* case of 15,634 jobs as a result of completion of Site stabilization and closure activities.

Within the Denver Metropolitan Area, the decrease in employment would also be substantial from activities under the *closure* case (forecasted decrease of 14,929 jobs).

Table 5.12-6. Changes in Site Employment in the Denver Metropolitan Area as Compared to the *Baseline Case*

Type of Change	*Baseline Case*	*Closure Case*
Direct–Site	5,204	**(4,835)**
Other Direct	2,694	**(2,626)**
Indirect	7,884	**(7,468)**
Total	15,782	**(14,929)**

Note: All changes in bold reflect a change of 10% or more and are considered to be substantial. Figures in parentheses indicate a decrease.

The decrease in annual payroll under the *closure* case, where annual payroll in Colorado would decline by $652.3 million from activities under the *baseline* case, would result from completion of Site stabilization and closure activities. (Table 5.12-7).

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Table 5.12-7. Changes in Site Payroll in Colorado as Compared to the *Baseline* Case

Type of Change[1]	*Baseline Case*	*Closure Case*
Direct–Site	$276,883,509	**($257,031,919)**
Other Direct	$104,072,438	**($101,803,201)**
Indirect	$307,503,530	**($293,508,103)**
Total	$688,459,477	**($652,343,223)**

[1]Constant 1994 dollars.

Note: All changes in bold reflect a change of 10% or more and are considered to be substantial. Figures in parentheses indicate a decrease.

Within the Denver Metropolitan Area, a substantial payroll decrease of $623.9 million under the *baseline* case would occur due to activities under the *closure* case. (Table 5.12-8).

Table 5.12-8. Changes in Site Payroll in the Denver Metropolitan Area as Compared to the *Baseline Case*

Type of Change[1]	*Baseline Case*	*Closure Case*
Direct–Site	$262,061,876	**($243,273,329)**
Other Direct	$100,897,749	**($98,721,491)**
Indirect	$295,277,600	**($281,964,020)**
Total	$658,237,225	**($623,958,840)**

[1]Constant 1994 dollars.

Note: All changes in bold reflect a change of 10% or more and are considered to be substantial. Figures in parentheses indicate a decrease.

5.12.3 Impacts on the Local Economy

The types of local economic indicators addressed in this section include 1) the purchase of goods and services by DOE and the Site contractor and 2) the effects on retail, office, and industrial real estate related to these purchases.

In addition to employing workers at the Site, the Site contractor and DOE purchase a range of goods and services from local and non-local vendors and suppliers through subcontracts and purchase orders. Purchases include engineering and technological consulting services, tools, office supplies, furniture, and a wide range of other products. All references to purchases in both cases are expressed in constant 1994 dollars.

As companies expand and contract, their demands for retail, office, and industrial space also expand and contract. This analysis used an input-output model to estimate the number of employees in various industrial sectors. Average standards regarding square feet of space per employee were applied to estimate the amount of retail, office, and industrial space occupied by companies from which the Site and its employees, plus the vendors and their employees, purchase goods and services.

Annual purchases of goods and services would decrease substantially from activities under the *closure* case as compared to activities under the *baseline* case. This $128.1 million decrease would be the result of the completion of cleanup activities during the study period.

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Similarly, within the Denver Metropolitan Area, activities under the *closure* case would result in a $122.7 million decrease in purchases of goods and services as compared to activities under the *baseline* case. These decreases would not result in substantial impacts (Table 5.12-9).

Table 5.12-9. Changes in Site Purchases in the Denver Metropolitan Area as Compared to the *Baseline Case*

Type of Change[1]	*Baseline Case*	*Closure Case*
Direct–Site	$211,971,707	**($205,700,133)**
Indirect	$1,080,911,114	**($1,022,026,430)**
Total	$1,292,882,821	**($1,227,726,563)**

[1]Constant 1994 dollars.
Note: All changes in bold reflect a change of 10% or more and are considered to be substantial. Figures in parentheses indicate a decrease.

Under the *closure* case, the reduction in purchases of goods and services from completion of cleanup activities would trigger a reduction in the demand for nonresidential space. As compared to activities under the *baseline* case, the reduction would be 3.5 million square feet for activities under the *closure* case. Decreases from activities under the *closure* case would not result in substantial impacts.

Within the Denver Metropolitan Area, the reduction in purchases of goods and services would also trigger a reduction in the demand for nonresidential space from activities under the *closure* case. Activities the under the *closure* case would result in a substantial reduction of 3.4 million square feet of nonresidential space as compared to activities under the *baseline* case (Table 5.12-10). Decreases from activities under the *closure* case would not result in substantial impacts.

Table 5.12-10. Changes in Private-Sector Nonresidential Space Demand Generated by Direct and Indirect Impacts in the Denver Metropolitan Area as Compared to the *Baseline Case*

Type of Change	*Baseline Case*	*Closure Case*
Retail	1,762,065	**(1,676,690)**
Office	1,107,403	**(1,057,345)**
Industrial	701,632	**(672,524)**
Total	3,571,100	**(3,406,559)**

Note: All changes in bold reflect a change of 10% or more and are considered to be substantial. Figures in parentheses indicate a decrease.

5.12.4 Impacts on Population and Housing

This analysis used standards for average employees per household and average persons per household to estimate the total household and population impacts associated with each case. Average annual salaries were estimated from salary information for on-site and off-site jobs. Salary information excludes the market value of any insurance benefits. Average household incomes were estimated from data regarding the average number of employees per household and average secondary wage earner income. The value of housing was based on a ratio of household income to housing values obtained from the latest available national survey research (USDL 1993a), assuming that one household occupies one housing unit. Estimates of average salaries, household income, and housing values are expressed in constant 1994 dollars.

This analysis quantified population, household income, and housing from the employment figures presented above. The actual impact on population and housing would be less than the figures reported below to the extent that people who lose their jobs would either find other jobs or retire but would tend to remain in the state or metropolitan area.

The slight changes in average income and household value figures between the two study years (peak year and 2006) is attributable only to changes in the occupation mix of on-site and off-site workers as all income is presented in constant 1994 dollars. The total income impact is discussed in Section 5.12.3, "Impacts on the Local Economy."

The State Demographer forecasts that population in the state will increase at an average annual rate of 1.4% between 1994 and 2006. The Denver Regional Council of Governments forecasts that population in the six-county metropolitan area will increase at an average annual rate of 1.2% between 1994 and 2006, with the assumption that Site-related employment will decrease by 4,000 jobs between 1994 and 1996 (DRCOG 1995b).

If all workers who lose jobs elect to leave the state, the impacts on population and households would be as shown below. To the extent that workers find replacement jobs or elect to retire and remain in the state, the impacts on population and households would be less.

The reduction in households and population as compared to activities under the *baseline* case would be substantial for activities under the *closure* case. (Table 5.12-11). Decreases from activities under the *closure* case would not result in substantial impacts.

Table 5.12-11. Households and Population in Colorado as Compared to the *Baseline Case*

Type of Change	*Baseline Case*	*Closure Case*
Households	11,809	**(11,167)**
Total Population	28,395	**(26,854)**

Note: All changes in bold reflect a change of 10% or more and are considered to be substantial. Figures in parentheses indicate a decrease.

Given that 95% of purchases are made in, and 95% of the employees reside in, the Denver Metropolitan Area, 95% of the household and population impacts would be within the metropolitan area. Again, the reduction in households and population would be substantial from activities under the *closure* case (Table 5.12-12). Decreases from activities under the *closure* case would not result in substantial impacts.

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Table 5.12-12. Households and Population in the Denver Metropolitan Area as Compared to the *Baseline Case*

Type of Change	*Baseline Case*	*Closure Case*
Households	11,273	**(10,644)**
Total Population	27,055	**(25,593)**

Note: All changes in bold reflect a change of 10% or more and are considered to be substantial. Figures in parentheses indicate a decrease.

5.12.5 Impacts on Quality of Life

This section discusses the impacts of both cases on quality of life issues in the Denver Metropolitan Area. Under all cases, the primary impacts on quality of life would involve potential health-related issues. These issues are addressed in Section 5.8, "Impacts on Human Health and Safety." The following discussion address non-health-related quality of life issues.

This analysis was based on a review of the cases presented in Chapter 3; consideration of demographic, employment and economic impacts; a review of documents prepared by other organizations regarding the changes in mission at the Site; interviews with planners and other officials; a qualitative analysis of environmental stigma issues; and an independent analysis of quality of life issues in the Denver Metropolitan Area (Adams 1991, BBC 1994, Belsten 1994, CDLE 1995a, EPS 1995, NCPP 1994a, Powell 1994b, RFLII 1994b, DOE 1995e, and USDL 1993a).

High quality of life in the Denver Metropolitan Area relates mostly to its moderate, four-season climate; proximity to wilderness, scenic, and natural amenities; an abundance of recreational opportunities; and the availability of nearby urban amenities including, upscale retail centers, professional sports teams, and cultural facilities such as theaters and museums. Additional quality of life concerns in the Denver Metropolitan Area include crime, air pollution, and a range of growth management issues such as traffic congestion, open space, and public education.

Excluding health-related concerns, the most notable quality of life impacts arising from remediation activities under the cases involve public perceptions of the Site and its surroundings. These impacts are speculative in that they relate to perceptions, which are dependent on the ultimate success of the proposed programs, media exposure, and other factors. These types of intangible impacts are recognized as important to an area's sense of well-being and community pride.

Activities under the *baseline* case would not substantially change the status of waste and materials at the Site and thus would not lessen negative perceptions of the Site and its surroundings. As conditions deteriorated over time, however, negative perceptions of the Site might worsen under this case. Activities under *closure* case might provide a benefit to the community, but the Site's continued status as a treatment and storage facility for nuclear waste might cause the public perception of progress to be less than favorable. Within the 10-year study period, activities under *closure* case could result in a unique positive impact because of the volume of decommissioning activity during this time period.

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5.13 Impacts on Environmental Justice

This section evaluates whether impacts under either of the cases would result in a disproportionately high or adverse effect on minority and low-income populations. Section 4.13, "Environmental Justice," presented an analysis of the composition of minority and low-income populations in the area surrounding the Site.

Table 5.13-1 summarizes environmental justice impacts for the *baseline* case and *closure* case. The potential for adverse human health effects from exposure to Site air emissions (both radiological and nonradiological) and from reasonably foreseeable accidents (facilities and transportation) is low under both the *baseline* case and *closure* case.

Table 5.13-1. Environmental Justice Impacts Summary

Description	*Baseline Case*	*Closure Case*
Disproportionately high or adverse human health or environmental impacts	Negligible	Negligible

Methodology

Within a 50-mile radius of the Site, the distribution of minority and low-income populations was identified and mapped, and the human health and environmental impacts associated with both cases were reviewed. The review included impacts on human health, air quality, water resources, socioeconomics, cultural resources, facility operations, and transportation associated with each case. Human health impacts were examined for both normal facility operations (incident-free) and accident conditions, with accident scenarios evaluated in terms of risk to the public. The examination of transportation included both normal and potential accident conditions for commuter traffic and truck transport of hazardous and radioactive materials.

Public health risk assessments focused on risks to the maximally exposed individual members of the off-site population surrounding the Site and in the evaluated transportation corridors (Figure 4.6-1). Only in cases in which the maximally exposed individuals are at high risk would there be a potential for disproportionately high or adverse health risks to minority or low-income communities. If risks to maximally exposed individuals were low, no segment of the population would experience disproportionately high or adverse health risks, including minority or low-income populations.

The assessment of environmental impacts focused on effects such as air quality impacts that would be likely to directly affect off-site populations. As with health risks, if environmental impacts in general were low, there would not be a potential for disproportionately high or adverse impacts on minority or low-income groups. Where risks or environmental impacts were found to be substantial, there would be a potential for high or adverse impacts on all populations.

Definition of Terms

For the environmental justice assessment, the following definitions were used:

Disproportionately High or Adverse Human Health Effects refers to effects that occur when the risk or rate of latent cancer fatalities as well as other fatal or nonfatal adverse impacts on human health for a minority population or low-income population from exposure to an environmental hazard substantially exceeds the risk or rate to the general population and, where data are available, to another appropriate comparison group.

Disproportionately High or Adverse Environmental Impacts refers to a deleterious environmental impact (or risk of an impact) determined to be unacceptable or above generally accepted norms in a low-income or minority community that substantially exceeds the same type of impact in the larger community. Assessments of cultural and aesthetic environmental impacts account for impacts that uniquely affect geographically dislocated or dispersed low-income or minority populations.

Distribution of Minority and Low-Income Populations refers to the detailed analysis of the composition of minority and low-income populations in the area surrounding the Site, as presented in Section 4.13, "Environmental Justice." Minority communities are not classified as disproportionate because the percentages are well below total county and state averages of minority populations. The population within 10 miles of the Site is predominantly non-Hispanic white. The bulk of the minority population in the region between 10 and 50 miles from the Site is concentrated in the City and County of Denver and western Adams County. The high concentration of minorities in Denver and Adams Counties contrasts with predominantly white communities in Arapahoe, Boulder, and Jefferson Counties. As with the distribution of minority population, areas with low median income contrast with areas with high median income. In the region between 10 and 50 miles from the Site, 65% of the population reported in the 1990 census an annual income greater than $30,000. The U.S. Bureau of Census characterizes $12,700 as the "statistical poverty level." The U.S. average median income is $30,000.

Study Area refers to 14-county region subdivided into two sections: the area from 0 to 10 miles from the Site and the area between 10 and 50 miles from the Site.

Summary of Impacts

The environmental justice assessment focused on the estimated impacts of radiological and nonradiological ambient air emissions resulting from Site facility operations and potential accidents as well as impacts from off-site transportation. Because of the location of the Site and its Buffer Zone, exposure routes through water or on other media are not expected to contribute to any health or environmental impacts.

No minority or low-income neighborhoods are located within a 10-mile radius of the Site, and no residential properties are located within 2 miles of the Site. The minority population within a 10-mile radius of the Site is below 20% of the total population within that radius. Since a minority population consists of a group that is greater than 50% minority, no population within 10 miles would be considered a minority population. Likewise, since the income level of residents within 10 miles exceeds the statistical poverty threshold, this population would not be classified as a low-income population.

The requirement to identify differential patterns of consumption of natural resources among minority populations is not applicable because the Site is located in an area with very little food crop production. Subsistence consumption of fish and wildlife in the urban and suburban environments surrounding the Site is not a substantial exposure route.

Incident-Free Operations

The following sections describe impacts on the public within a 50-mile radius of the Site that would result from radiological and nonradiological air emissions during incident-free operations for the 10-year CID timeframe.

RADIOLOGICAL EMISSIONS. As described in Section 4.8.2, "Radiological Health and Safety–Public," the air pathway is the only substantive pathway by which the general public within a 50-mile radius of the Site would be affected by radioactive releases. Under all cases, the number of off-site excess latent cancer fatalities due to radioactive releases from normal operation of Site facilities and activities under all of the cases would be much less than 1. This level of increased risk is negligible when compared to the level of risk to the public due to other sources of radiation.

Figures 5.13-1 and 5.13-2 depict the estimated radiation dose for each case (in millirem per year) overlain on maps showing the distribution of minority and low-income populations, respectively. The dose estimates for both cases are well below all established health and environmental limits. Estimated emissions of radionuclides are well below applicable standards and legal limits. Therefore, no disproportionately high or adverse impacts from radiological air emissions are anticipated for any segment of the population, including minority and low-income populations.

NONRADIOLOGICAL EMISSIONS. The total risk (hazard index) from air releases of nonradiological toxic chemicals is 1.3 for the *baseline* case and 1.5 for the *closure* case. These estimates indicate a low risk of adverse health effects to the off-site public from inhalation of air emissions under both cases.

Nonradiological air emissions for both cases would not exceed any standards or impose adverse human health or environmental effects. Emissions of criteria air pollutants and hazardous air pollutants under both cases would be well below applicable standards. Therefore, no disproportionately high or adverse impacts from nonradiological air emissions are anticipated, for any segment of the population, including minority and low-income populations.

Reasonably Foreseeable Accidents

Risk to the public from facility accidents is a function of both the potential accident consequences and the probability of occurrence. It is also unlikely that any of the accidents leading to these health consequences would occur.

Impacts from high-consequence, low-probability accident scenarios would be adverse if they occurred; however, the impacts on specific population locations would be dependent on meteorological conditions on the day of the accident. Whether or not such impacts would have disproportionately high or adverse effects with respect to any particular segment of the population, including minority and low-income populations, would be subject to random meteorological factors. Prevailing wind patterns at the Site are described in Section 4.5.1, "Meteorology." However, because the probability of occurrence of such accidents is extremely low, the risks to any segment of the population, including minority and low-income groups, is low.

Impacts from Transportation

The assessment of transportation impacts under each case is presented in Section 5.6, "Impacts on Traffic and Transportation," and Appendix A "Traffic and Transportation." On-site transportation was not considered in the environmental justice analysis because no adverse human health impacts on any segment of the general population are expected from on-site transportation. In general, off-site transportation impacts would be due to truck shipments from the Site and commuter traffic to and from the Site.

INCIDENT-FREE TRANSPORTATION IMPACTS. Radiation-related fatalities are latent cancer fatalities that would occur along the transportation corridors as a result of radiation exposure from radioactive waste shipped from the Site. Vehicle-related fatality estimates are fatalities that would occur along the transportation corridors as a result of inhalation of vehicle emissions.

The majority of incident-free vehicle-related fatalities would be due to commuter traffic. Commuter traffic would not result in disproportionately high or adverse impacts on minority or low-income populations because commuters come from various communities throughout the area. Minority and low-income populations are dispersed throughout the 50-mile radius. The majority of commuters do not travel from areas of low income or minority communities.

Trucking routes from the Site follow major state and interstate highways that pass through both high- and low-income communities as well as both predominantly white and minority communities (Figure 4.6-1).

All trucking routes from the Site exit from the East Access Road to Indiana Street, follow State Highway 128 east to U.S. Highway 36, and U.S. Highway 36 east to its intersection with Interstate 25. Under both cases, shipments to Hanford and Envirocare in Utah would follow Interstate 25 north, shipments to Waste Isolation Pilot Plant would follow Interstate 25 south, and shipments to the Nevada Test Site would follow Interstate 25 south to U.S. Highway 76, and then west to Interstate 70 west. All of these routes pass through predominantly low-income and minority communities near the intersection of U.S. Highway 36 and Interstate 25. However, all routes quickly exit these communities and enter regions of higher income and predominantly white communities within a 50-mile radius of the Site. Based on the locations of the trucking routes from the Site, no disproportionately high or adverse human health or environmental impacts on minority and low-income populations in the region are expected from transportation under either of the cases.

TRANSPORTATION ACCIDENT IMPACTS. Radiation-related accident fatalities are latent cancer fatalities that would occur along the transportation corridors as a result of radiation exposure from accidents involving radioactive waste shipped from the Site. Vehicle-related accident fatality estimates are fatalities that would occur along the transportation corridors as a result of vehicle accidents.

The majority of vehicle-related accident fatalities are due to commuter traffic. Commuter traffic would not result in disproportionately high or adverse impacts on minority or low-income populations because commuters come from various communities throughout the area.

Trucking routes from the Site follow major state and interstate highways that pass through both high- and low-income communities as well as both predominantly white and minority communities (Figure 4.6-1). Based on the locations of the trucking routes from the Site, no disproportionately high or adverse human health or environmental impacts on minority and low-income populations in the region are expected from transportation accidents under both cases.

Environmental Impacts

Impacts on ecological or cultural resources would not affect low-income and minority populations. Minority or low-income populations do not use any specific historic, cultural, or ecological resources within the study area, so no disproportionate effects would occur. Sensitive ecological resources would be protected and preserved as necessary, as discussed in Section 5.9, "Impacts on Ecological Resources."

Socioeconomic Impacts

Socioeconomic impacts from Site activities would not affect minority or low-income populations disproportionately since Site employees in the Denver County area (which has the highest percentage of minorities) only comprise 0.1% of the total county labor force. Additionally, laborers at the Site constitute only 9% of its total labor force.

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Figure 5.13-1. Minority Population Distribution and Estimated Radiation Dose Contours for Both Cases

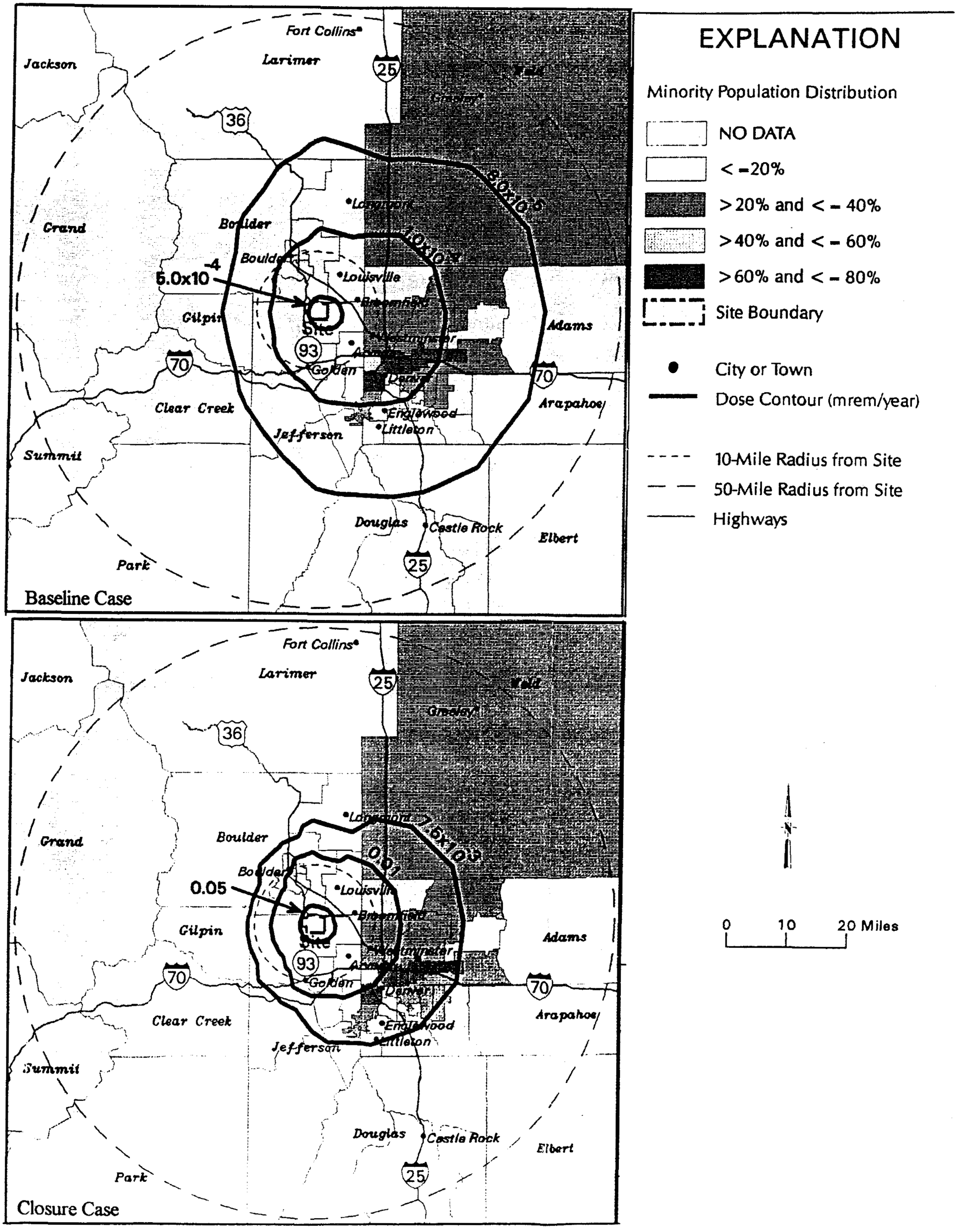

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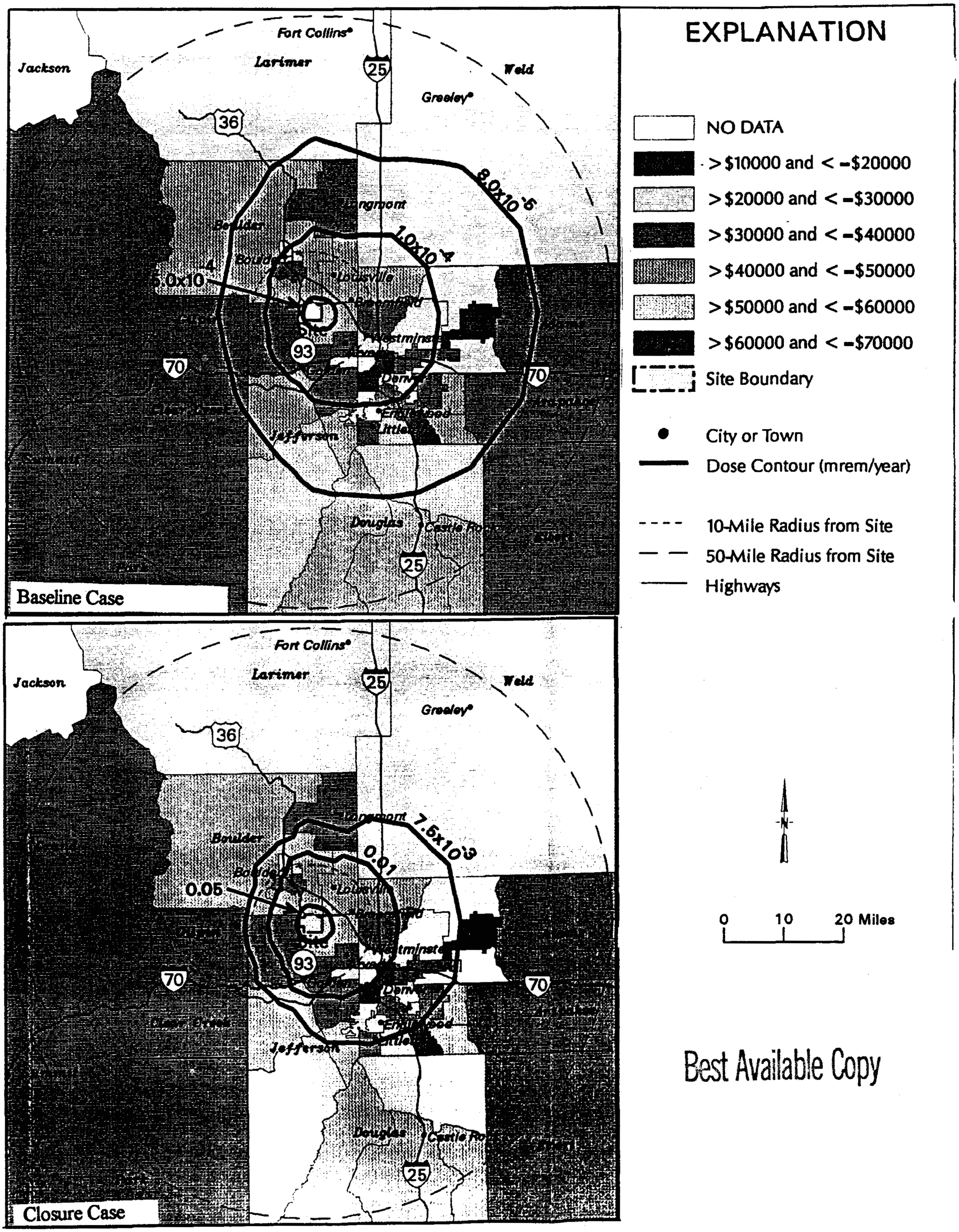
Figure 5.13-2. Median Income Distribution and Estimated Radiation Dose Contours for Both Cases



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5.14 Impacts Resulting from Potential Accidents

The impacts of hypothetical accident scenarios are evaluated for this CID in terms of risks to the public and co-located worker, considering both possible consequences and probability of occurrence. Risks from accidents are assessed quantitatively as the product of a scenario probability of occurrence times its consequences; risks from individual accident scenarios are then added to provide a perspective of risk for various accident categories (e.g., fires, spills, criticalities, aircraft crash, seismic, etc.) and for the entire Site. A reasonable representation of risk is provided by evaluating a spectrum of accidents, including those bounding accidents that are generally associated with low probabilities, as well as more likely accidents with less consequences that may be risk-significant. An accident is considered bounding if no reasonable foreseeable accident can be found with greater consequences. An accident is reasonably foreseeable if the analysis of occurrence is supported by credible scientific evidence, is not based upon pure conjecture, and is reasonable (40 CFR 1502.22[b][4]). However, the risk from bounding consequence accidents may not be risk dominant which is why a spectrum of accident likelihoods are analyzed. These risks are developed for radiological and nonradiological accidents.

This section describes the accident analysis for the *baseline* and *closure* cases. The accident screening methodology is described, the postulated accident scenarios selected for quantification are discussed, and the development of source terms (environmental releases) for those accidents is described. Accident scenario frequencies, source terms, and impacts are also discussed. Additional information is provided in Appendix C, "Accidents." Transportation accidents are discussed in Section 5.6, "Impacts on Traffic and Transportation."

The Site establishes Site or facility operational safety parameters in final Safety Analysis Reports, Basis for Interim Operations reports, Basis for Operation reports, and Emergency Planning accident analyses. These reviews and the accompanying reports provide interim or final authorization basis upon which safe operation of a nuclear facility or planned activities are based. Emergency Planning documents provide effective planning should an accident occur to best protect workers and the public from the consequences of that accident. This CID accident analysis is not intended to replace any of these reviews and analyses that are current or any of those to be performed in the future. The CID provides an independent accident analysis to allow an analytical comparison of the *closure* case to the *baseline* case, and how that risk may change over time as the Site *closure* case is implemented.

Consequence estimates are developed for dose (Effective Dose Equivalent (EDE) or Committed Effective Dose Equivalent (CEDE)) to the Maximally Exposed Off-site Individual (MOI) located at the minimum site boundary distance of 1.9 kilometers (km) from the center of the plutonium buildings (or at a greater distance if the dose is larger due to lofting of the release from a fire), latent cancer fatalities from collective dose to the general population surrounding the Site within a radius of fifty miles (i.e., approximately 2.2 million people), and dose to a hypothetical co-located worker at a distance of 100 meters (m) from the location of the accident.

To adequately assess a risk envelope, it is necessary to determine the source term, the probability or frequency that the accident will occur, and the consequences to the worker or member of the public. The accident frequency is based on the probability of occurrence of an initiating event (i.e., failure of preventive safety systems) and the success or failure probabilities of mitigating safety systems. The source term is the estimate of the amount of material, usually plutonium, made airborne and available to a receptor. The source term is converted to a concentration in air to which an individual could be exposed. Based on duration of exposure, a radiological dose commitment or an estimate of latent cancer fatalities for an individual or population are made.

Conservative assumptions regarding source terms are made throughout the assessment based on the Site's current operations and projected future activities as defined in the CID *baseline* and *closure* cases. However, a realistic estimate of risk is presented by considering the mostly likely probability of occurrence and consequences based on typical weather conditions. By providing realistic estimated risks from accidents, decision makers are able to distinguish which future activities provide the largest overall reduction in accident risk. Although risk estimates are presented with one or more significant digits, these numerical estimates have a large range of uncertainty and should be viewed as order-of-magnitude estimates. Appendix C, "Accidents," provides a further discussion of uncertainty in risk estimates.

5.14.1 Radiological Accident Analysis

Activities and Assumptions

Activities postulated or delineated for the *baseline* case or *closure* case serve as the set of conditions or assumptions for which the risk estimates are valid. The estimated risks may not be valid if the activities or assumptions are changed. Discussed below are some of the key activities or assumptions utilized in this CID accident analysis.

For the *baseline* case, Chapter 3, "Description of *Baseline* and *Closure* cases" describes those activities that occurred during 1996 and building inventories of SNM, plutonium residues, and TRU waste. In addition to maintaining safe storage of these materials, some plutonium operations continued (e.g., thermal stabilization, liquid stabilization, residue characterization, etc.), as well as maintenance of the plutonium buildings' safety and security systems. Some SNM consolidation occurred by eliminating most of B779's and B991's plutonium inventory to Building 371. Some environmental restoration activities occurred, including treatment and storage of generated wastes. Some facility DD&D activities were started, including deactivation of Buildings 779 and 886 and demolition of a few non-plutonium facilities.

The accident analysis for the *baseline* case is based on material being present in multiple buildings subject to several internal and external accident initiators. A graphical representation of this inventory is shown in Figure 5.14-1, along with each building's contribution to Site risks based on the risk assessment described in this section. Under these conditions, several accidents can result in the release of plutonium to the environment. Risks to the public and co-located worker from accidents are dominated by plutonium oxides (and americium in plutonium residues) rather than from plutonium metal or enriched or depleted uranium or other isotopes (however, radionuclides generated during a criticality accident were evaluated).

Activities involved with the *closure* case are described in Chapter 3, "Description of *baseline* and *closure* cases." This involves moving radioactive materials (SNM, residues, TRU/TRU-mixed waste, low-level/low-level mixed waste) between various buildings for treatment, repackaging, interim storage, or off-site shipment. All plutonium buildings will be deactivated, decontaminated, and decommissioned by the Year 2010. Plutonium building safety systems would be deactivated after removable holdup in equipment, piping, and ventilation ductwork is removed. This is an important consideration for accident analysis because it is an indication to what extent vital safety systems will be maintained to protect the worker and the public should an accident occur. The CID assumes that during these activities from material consolidation to DD&D, safe radiological practices are followed, localized containment is provided by functional HEPA filtration systems (either the building nuclear ventilation system or portable contamination control cells), and localized monitoring would alert Site safety personnel to increasing levels of radioactivity in the environment. During decontamination after most of the holdup is removed, the quantity of facility material-at-risk is small. Therefore, accident impacts due to these activities would be bounded by other accidents involving more substantial inventories of material-at-risk (e.g., SNM waste, TRU waste, or residues).

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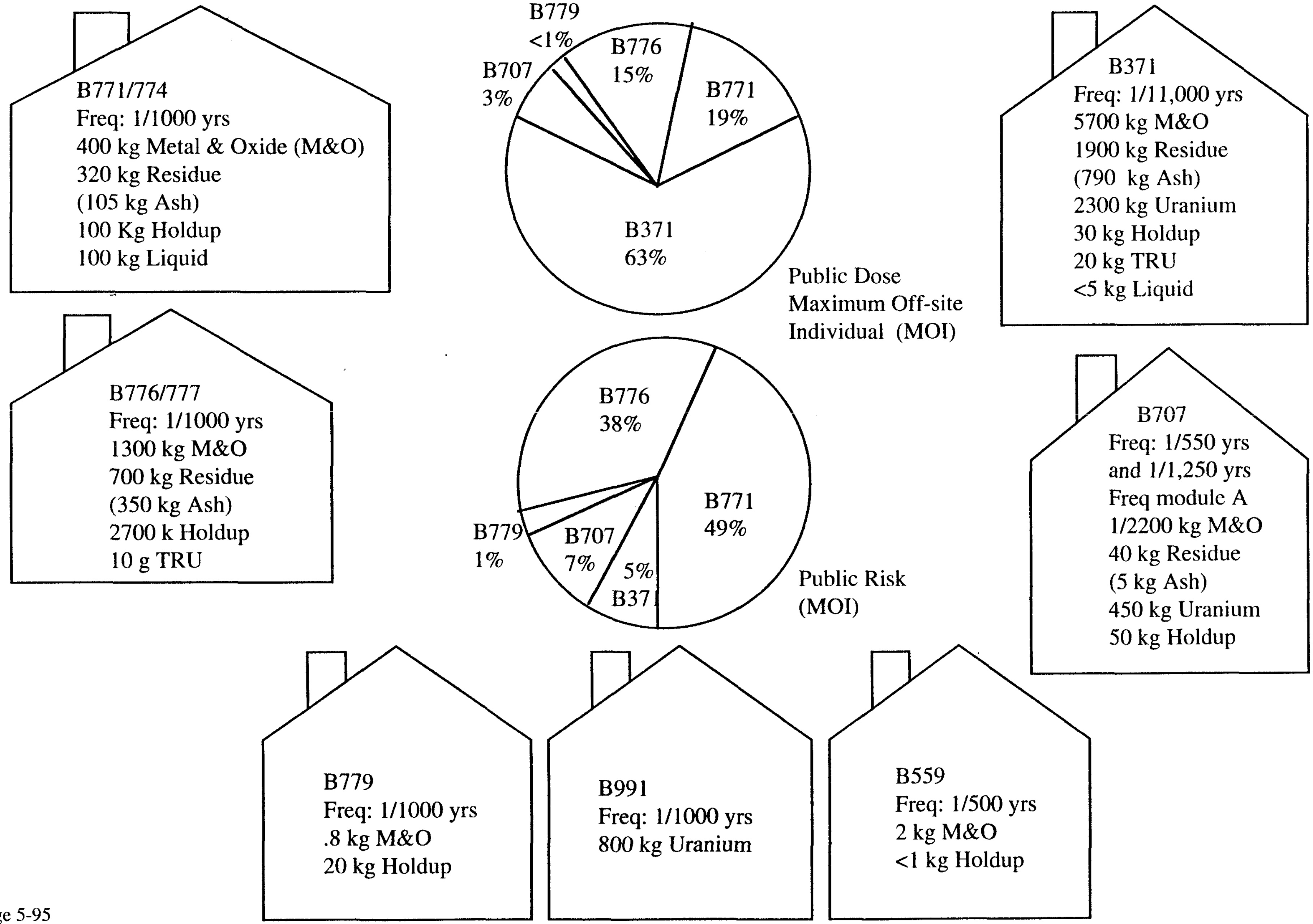
Figure 5.14-1 Baseline Case Inventory Profile/Contribution To Seismic Risk By Building



Accident Initiators

In order to support preparation of an accident analysis and source terms for the CID *baseline* and *closure* cases, it is first necessary to identify those accident contributors which must be analyzed for environmental impact. This is accomplished by conducting a "screening" analysis to identify those accident initiators which are recognized to be unimportant contributors to risk, leaving those accident initiators that are potentially important risk contributors.

Three general classes of events were considered: "internal initiators," "natural phenomena initiators," and "external initiators." Internal initiators are those events originating with the Site facility (facilities) or area which result from the placement of materials-at-risk and which do not require an external influence (e.g., various combinations of component or system failures and/or human errors). Natural phenomena initiators are those events originating outside the facility or area and include such events as floods and tornadoes. External initiators are potential accident events originating outside the facility or area and include a variety of manmade hazards (e.g., aircraft crash).

The screening methodology used in identifying potential event initiators (internal, natural phenomena and external) as candidates for accident screening is included in Appendix C "Accidents." This methodology is applied to produce a screening analysis for the facility or area considered in each alternative. Accident screening parameter values were developed as appropriate. By considering the events that survived the initial screening as well as the accident parameters and values, the final list of accidents to be evaluated was refined. Accident frequencies were estimated and accident source terms were developed as described below. Using the frequencies and source terms, doses and risks to receptors were calculated.

Radiological Accident Analysis Methodology

The approach adopted for accident screening for the Site is a variation of an approach called "progressive screening." Accident screening has three important goals:

1. The analysis should be complete in that all credible events are considered.
2. By following screening criteria, events with a higher potential for risk are identified for more detailed analysis.
3. The selected events are analyzed in depth by taking into account the unique features of the potential hazard posed by the event, the resistance of structures and equipment to the environment created by the event, and the frequency (likelihood) of the initiating event.

Several steps are required to implement this method:

1. Screening criteria are defined.
2. Master lists of potential internal, natural phenomena, and external event initiators are formulated.
3. A progressive screening analysis is performed for events that are not applicable to the Site. These are screened from further analysis (e.g., coastal erosion would have no impact on a facility located far inland).
4. For events passing the first stage of screening, a conservative bounding analysis is performed to ascertain if the event frequency exceeds 1×10^{-6} per year (conservatively assessed) or 1×10^{-7} per year (realistically assessed). If the event frequency falls below these screening values, no further analysis is performed (i.e., the event screens).

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A set of screening criteria was formulated to minimize the possibility of omitting substantial risk contributors while reducing the amount of detailed analyses to manageable proportions. Application of the screening criteria, and reasoning employed for each accident type is presented in Appendix C, "Accidents." Using the screening criteria, the following accidents were screened from further analysis:

Avalanche	Fog	Low lake or river water level	Soil shrink-swell consolidation
Biological events	Frost	Meteorite or asteroid impact	Temperature extremes
Climatic change	Hail	Nearby industrial facility accidents	Tornadoes
Coastal erosion	High tides, high lake/river level	Pipeline accidents	Tsunamis
Dam failure	Ice	River diversion	Turbine missiles
Drought	Internal fires (except dock fires)	Sabotage and terrorism	Volcanic activity
Dust storms	Internal flooding	Sandstorms	Waves
External fires	Landslides	Satellite orbital decay	
External flooding	Lightning	Snow	

Identification of Accident Scenarios for the Site

Following the screening analysis, the following accidents remained for detailed analysis:

- Fires within buildings and on the dock
- Explosions within buildings from flammable gases or other sources
- Spills of plutonium oxide or solutions
- Criticality (unanticipated or unintended chain reaction involving SNM, either plutonium or highly enriched uranium)
- Aircraft crash into plutonium buildings (including post-crash fire effects)
- Earthquakes (several levels of severity including earthquakes sufficiently severe to result in structural collapse of all plutonium buildings at the Site)
- High winds (other than tornadoes, which were screened)

Numerous accident scenarios were evaluated for these accident categories as presented in Appendix C, "Accidents." However, only risk-dominant scenarios for each accident category are summarized in this section. On-site transportation accidents were also evaluated and are described in Section 5.6, "Traffic and Transportation."

Accident Sequence Frequency

Using Site-specific data (to the extent available) and realistic assumptions, the frequencies of the accident scenarios were calculated. Table 5.14-1 summarizes the accident scenario frequencies. It should be noted that there may be multiple initiators for the same event. For example, there are several earthquakes different in magnitude and different in their expected frequency of occurrence that can cause failure of each plutonium buildings. There may be cases in which an accident

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scenario has large projected consequences (e.g., dose to the MOI or co-located worker, or population LCFs), but the probability that it will occur is extremely remote and therefore its risk is also low. Conversely, an accident with relatively small consequences may be of substantial concern because it is predicted to occur relatively often.

Table 5.14-1. Bounding Accident Scenario Frequency Summary

Accident Scenario	*Baseline Case* (per year)	*Closure Case* (per year)
SNM Vault Fire	4×10^{-7}	1×10^{-6}
Pu Dock Fire - High-Am Residues	2×10^{-6}	8×10^{-6}
Waste Facility - 1 LLW Crate Fire	5×10^{-2}	5×10^{-2}
Waste Facility - 15 LLW Crate Fire	5×10^{-3}	5×10^{-3}
Waste Facility - TRU Drum Fire	3×10^{-3}	7×10^{-3}
Oxyacetylene Explosion in Pu Bldg.	2×10^{-4}	2×10^{-4}
Pu Dock Spill - Oxide	1×10^{-3}	4×10^{-3}
Pu Dock Spill - Residue Drum	1×10^{-3}	4×10^{-3}
Uranium Solution Criticality	1×10^{-3}	eliminated
Plutonium Solution Criticality	2×10^{-4}	2×10^{-4}
Plutonium Oxide Criticality	5×10^{-4}	5×10^{-4}
Aircraft Crash	varies	varies
Seismic Collapse of Bldg. 559 and TRU Waste Storage Buildings	2×10^{-3}	2×10^{-3}
Seismic Collapse of Building 707 Modules A through H	1.8×10^{-3}	1.8×10^{-3}
Seismic Collapse of Building 707 Modules J & K, and Bldg. 779	8×10^{-4}	8×10^{-4}
Seismic Collapse of Bldg. 374	1.1×10^{-3}	1.1×10^{-3}
Seismic Collapse of Bldgs. 771, 774, 776/777, and 991 TRU storage	1×10^{-3}	1×10^{-3}
Seismic Collapse of Bldg. 371	2.9×10^{-5}	2.9×10^{-5}
High Winds	1×10^{-4}	1×10^{-4}

Accident Source Terms

The source term is the estimate of the amount of material, usually plutonium, made airborne and available to a receptor (worker or member of the public). The source term is converted to a concentration in air to which an individual could be exposed.

The material at risk for a given accident scenario was developed from unclassified sources (some of which were "Unclassified Controlled Nuclear Information") and classified sources. In some cases (such as spills and dock fires), the material at risk was characterized on the basis of package inventory limitations. In other cases, the material at risk was defined on the basis of damage caused by the initiating event and subsequent failures. Unclassified and classified building inventories (expressed in total quantity of SNM) were used as background information.

Nearly all radiological releases considered in the CID consist of various fractions of weapons-grade plutonium (the only exceptions are the criticality source terms). The isotopic composition of the weapons-grade plutonium is identified in Appendix C, "Accidents." Criticality events result in a chain reaction and fissioning of SNM (either plutonium or highly enriched uranium). Fissioning results in the production of fission products (e.g., radioactive noble gases such as krypton and

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xenon as well as other fission products such as iodine, cesium, and strontium) that can be released from the criticality site.

Release fractions were selected from the range of values in the literature (Site risk assessments and other DOE documentation). The airborne release fraction is the fraction of the material at risk that is suspended in air as an aerosol and thus available for transport due to stresses from a specific accident. The respirable fraction is that fraction of airborne particulates that can be transported through air and inhaled into the human respiratory system and is commonly assumed to include particles 10-μm (microns or micrometers) Aerodynamic Equivalent Diameter and less (inhalable particles).

The release fractions depend significantly on the physical form of the material, and the stresses produced by the particular accident. In general, material at risk that is in particulate form (such as oxides) has a higher release fraction than solid metals or liquids.

The airborne release fractions used in the current analysis reflect the circumstances of the accident being evaluated (e.g., a plutonium powder spill versus a fire involving plutonium metal). Additional information concerning release fractions for each accident type is presented in Appendix C, "Accidents."

Estimated respirable source terms, which take into account the release fractions, as well as any applicable damage ratios and leakpath factors for building confinement (e.g., HEPA filtration), for the bounding radiological accidents are summarized in Table 5.14-2.

Table 5.14-2. Bounding Accident Source Term Summary

Accident Scenario	*Baseline Case* (g Pu or # fissions)	*Closure Case* (g Pu or # fissions)
SNM Vault Fire	$1 \times 10^{+2}$	$1 \times 10^{+2}$
Pu Dock Fire - High-Am Residues	2×10^{-1}	2×10^{-1}
Waste Facility - 1 LLW Crate Fire	2×10^{-1}	2×10^{-1}
Waste Facility - 15 LLW Crate Fire	2×10^{0}	2×10^{0}
Waste Facility - TRU Drum Fire	1×10^{-1}	1×10^{-1}
Oxyacetylene Explosion in Pu Bldg.	4×10^{0}	4×10^{0}
Pu Dock Spill - Oxide	4×10^{-1}	4×10^{-1}
Pu Dock Spill - Residue Drum	2×10^{0}	2×10^{0}
Uranium Solution Criticality	6.2×10^{20} fissions	eliminated
Plutonium Solution Criticality	1×10^{19} fissions	1×10^{19} fissions
Plutonium Oxide Criticality	1×10^{19} fissions	1×10^{19} fissions
Aircraft Crash	varies	varies
Seismic Collapse of Bldg. 559	1×10^{-1}	1×10^{-1}
Seismic Collapse of TRU Waste Storage Butler-type Buildings	1×10^{-1}	1×10^{-1} (but increases by 10 as residues are processed)
Seismic Collapse of Building 707 Modules A through H	5×10^{0} (+0.014g Am)	$2.7 \times 10^{+1*}$
Seismic Collapse of Building 707 Modules J & K	$2.9 \times 10^{+1}$	$2.9 \times 10^{+1}$
Seismic Collapse of Bldg. 779	3×10^{0}	3×10^{0}
Seismic Collapse of Bldg. 374	3×10^{-2}	3×10^{-2}
Seismic Collapse of Bldg. 771/774	$9.6 \times 10^{+1}$ (+1.1g Am)	$9.6 \times 10^{+1}$ (+1.1g Am)
Seismic Collapse of Bldg. 776/777	$1.1 \times 10^{+2}$	$1.1 \times 10^{+2}$
Seismic Collapse of Bldg. 991 TRU storage	1×10^{-1}	1×10^{-1}
Seismic Collapse of Bldg. 371	$4.0 \times 10^{+2}$ (+2.5g Am)	$4.0 \times 10^{+2}$ (+2.5g Am)
High Winds	2×10^{0}	2×10^{0}

*Future Am increase to be managed with Pu such that Am dose contribution is included in the "Pu-equivalent" release amount.

A nuclear criticality may be characterized by a flash of fissions that produce a pulse of penetrating radiation, followed by a period of much lower radiation lasting from a few minutes to several hours depending on the self-limiting properties of the critical mass. A criticality is very different from a nuclear detonation, which is instantaneous fissioning of all fissionable material. There is no potential for a nuclear detonation at the Site.

Radiological Accident Impacts Assessment

For each radiological accident that satisfied the screening criteria, calculations were performed to estimate the resultant impacts on workers and members of the public. MACCS was used for individual and collective doses as well as latent cancer fatalities estimated to occur within a 50-mile radius of the Site. Additional details of the calculations are presented in Appendix C, "Accidents."

The effects of radiation exposures were estimated in excess latent cancer fatalities within the exposed population. The risk factors of the International Commission on Radiological Protection's Publication 60 (ICRP 1991b) were used to generate the estimates of the effects that might be incurred by the exposed population in the event of a radiological accident.

The MACCS code is widely used for radiological accident analysis and other DOE NEPA, safety analysis, and risk assessment studies. MACCS allows consideration of only simple parent-daughter decay (i.e., chains limited to only two members). For accidents other than criticality, radionuclides considered in the calculations are plutonium-238/-239/-240/-241, and americium-241. Plutonium-242 was not included; this omission has a negligible effect on the calculated impacts because plutonium-242 is a very small fraction of the total radioactivity of the weapons grade plutonium, and its dose conversion factor is slightly less than that of plutonium-239.

MACCS2 (Chanin 1995) is under development by Sandia National Laboratories as a replacement of MACCS and is currently in beta-test status, with distribution to over 30 recipients in the United States and abroad (including RFETS). Beta-test Version 1.10 of the code was used for plutonium releases and criticality calculations. Because of its beta-test status, a set of confirmatory calculations for a maximum credible accident using weapons-grade plutonium were performed to verify that given the same input parameters, MACCS and MACCS 2 generated identical results. This was found to be the case.

Consequences were assessed for members of the public and co-located workers probabilistically, using 1992 meteorological data recorded at the Site's 61 meter weather tower. The meteorological data file was prepared by Site staff and is used as a standard for analyses performed to support both the authorization basis of facility operation (e.g., Safety Analysis Reports) as well as environmental assessments performed by Site staff (EG&G 1994v).

The MACCS atmospheric model allows consideration of time-variant meteorology during a weather sequence. By allowing consideration of time-variant meteorology during transport, the possible influence of precipitation at a downwind distance is automatically considered. This allows, for example, consideration of the risks posed by accidental releases that occur during dry conditions (with no precipitation) but that become affected by precipitation after the plume has traveled downwind and reached areas of higher population density.

Radiological impacts to workers in the immediate vicinity of the accident were not assessed in a quantitative manner because the code is not an appropriate tool for the estimation of doses within buildings or in their immediate vicinity. In the immediate vicinity of a building (within 100 meters), building wake effects are an important determinant of dose. The code employed does not incorporate a model suitable for the estimation of dose to workers within the building wake. Impacts on immediate workers are thus addressed in a qualitative manner.

In assessing co-located worker impacts, doses were calculated at a distance of 100 meters. For elevated releases, the maximal co-located worker dose may not always be at the closest (100 m) receptor point.

In assessing maximal off-site individual doses, it was assumed that a member of the public is located at a distance of 1.9 km from the Site's Protected Area. Maximally exposed members of the public were assumed to be outdoors for an exposure period of two hours, with no credit taken for the shielding effects of buildings. These assumptions are standard practice for DOE safety analyses. It is very likely that within two hours, activation of the on-site emergency response procedures would notify any individuals in the proximity, and those individuals would be assisted in exiting the region.

Collective doses and excess latent cancer fatalities among the general public were calculated for approximately 2.2 million people within 50 miles of the Site, and without applying demographic projections for the *closure* case timeframe until the Site is completely closed. For perspective, the Year 2006 (DOE 1995e) projection indicates a 20% increase in population to approximately 2.7 million people. These 50-mile population estimates are approximately 10% higher than the estimates presented in Section 5.12, "Impacts on Socioeconomics" which was based on the Denver metropolitan area. The 50-mile population estimates are discussed in Appendix B, "Human Health and Safety." This 50-mile population could approach 3 million people near the end of the *closure* case timeframe.

For members of the public, the following consequence measures were estimated: maximal off-site individual dose and collective dose to the public incurred within a 50-mile radius of the Site. The collective impacts among the general public were calculated by assuming a one-week exposure period.

The consequence measures reported for radiological impacts of accidents at fixed facilities (Site buildings) are as follows:

1. Maximal dose to on-site co-located workers.
2. Dose to a maximally exposed individual of the public residing near the Site's fence boundary.
3. Excess latent cancer fatalities to off-site populace within a 50-mile radius of the Site.

All doses are calculated as the total committed effective dose with a 50-year commitment period.

The detailed risk input parameters for each postulated accident for each of the CID *baseline* and *closure* cases are presented in detail in Appendix C, "Accidents."

Radiological Consequences and Risks

Table 5.14-3 summarizes the on-site, site boundary, and exposed general population health consequences as a result of the releases estimated for the various accidents postulated for each of the *baseline* and *closure* cases. Similarly, Table 5.14-4 summaries risks to the respective receptors.

Table 5.14-3. Radiological Consequences From Bounding Accident

Accident Scenario	Baseline Case: Co-located Worker Dose (rem)	Baseline Case: Maximum Off-site Individual Dose (rem)	Baseline Case: Population Latent Cancer Fatalities	Closure Case: Co-located Worker Dose (rem)	Closure Case: Maximum Off-site Individual Dose (rem)	Closure Case: Population Latent Cancer Fatalities
SNM Vault Fire	9×10^{-1}	3×10^{0}	2×10^{0}	9×10^{-1}	3×10^{0}	2×10^{0}
Pu Dock Fire - High-Am Residues	$1 \times 10^{+1}$	1×10^{-1}	2×10^{-2}	$1 \times 10^{+1}$	1×10^{-1}	2×10^{-2}
Waste Facility - 1 LLW Crate Fire	2×10^{0}	2×10^{-2}	2×10^{-3}	2×10^{0}	2×10^{-2}	2×10^{-3}
Waste Facility - 15 LLW Crate Fire	$2 \times 10^{+2}$	6×10^{-2}	3×10^{-2}	$2 \times 10^{+2}$	6×10^{-2}	3×10^{-2}
Waste Facility - TRU Drum Fire	1×10^{0}	1×10^{-2}	2×10^{-3}	1×10^{0}	1×10^{-2}	2×10^{-3}
Oxyacetylene Explosion in Pu Bldg.	$5 \times 10^{+1}$	4×10^{-1}	6×10^{-2}	$5 \times 10^{+1}$	4×10^{-1}	6×10^{-2}
Pu Dock Spill - Oxide	6×10^{0}	5×10^{-2}	6×10^{-3}	6×10^{0}	5×10^{-2}	6×10^{-3}
Pu Dock Spill - Residue Drum	$2 \times 10^{+1}$	2×10^{-1}	2×10^{-2}	$2 \times 10^{+1}$	2×10^{-1}	2×10^{-2}
Uranium Solution Criticality	$4 \times 10^{+2}$	2×10^{0}	4×10^{-2}	–	–	–
Plutonium Solution Criticality	2×10^{0}	1×10^{-2}	6×10^{-4}	2×10^{0}	1×10^{-2}	6×10^{-4}
Plutonium Oxide Criticality	2×10^{-1}	1×10^{-3}	6×10^{-4}	2×10^{-1}	1×10^{-3}	6×10^{-4}
Aircraft Crash	varies	varies	varies	varies	varies	varies
Seismic Collapse of Bldg. 559	2×10^{0}	2×10^{-2}	2×10^{-3}	2×10^{0}	2×10^{-2}	2×10^{-3}
Seismic Collapse of TRU Waste Storage Butler-type Buildings	2×10^{0}	2×10^{-2}	2×10^{-3}	2×10^{0}	2×10^{-2}	2×10^{-3}
Seismic Collapse of Building 707 Modules A through H	$7 \times 10^{+1}$	6×10^{-1}	8×10^{-2}	$3.9 \times 10^{+2}$	3.1×10^{0}	4×10^{-1}
Seismic Collapse of Building 707 Modules J & K	$4 \times 10^{+2}$	3.3×10^{0}	4×10^{-1}	$4 \times 10^{+2}$	3.3×10^{0}	4×10^{-1}
Seismic Collapse of Bldg. 779	$4 \times 10^{+1}$	3×10^{-1}	4×10^{-2}	$4 \times 10^{+1}$	3×10^{-1}	4×10^{-2}
Seismic Collapse of Bldg. 374	4×10^{-1}	3×10^{-3}	5×10^{-4}	$4 \times 10^{+1}$	3×10^{-3}	5×10^{-4}
Seismic Collapse of Bldg. 771/774	$2.4 \times 10^{+3}$	$1.9 \times 10^{+1}$	2.6×10^{0}	$2.4 \times 10^{+3}$	$1.9 \times 10^{+1}$	2.6×10^{0}
Seismic Collapse of Bldg. 776/777	$1.8 \times 10^{+3}$	$1.5 \times 10^{+1}$	$2x 10^{0}$	$1.8 \times 10^{+3}$	$1.5 \times 10^{+1}$	$2x 10^{0}$
Seismic Collapse of Bldg. 991 TRU storage	1×10^{0}	1×10^{-2}	2×10^{-3}	1×10^{0}	1×10^{-2}	2×10^{-3}
Seismic Collapse of Bldg. 371	$7.9 \times 10^{+3}$	$6.4 \times 10^{+1}$	8.6×10^{0}	$7.9 \times 10^{+3}$	$6.4 \times 10^{+1}$	8.6×10^{0}
High Winds	$3 \times 10^{+1}$	2×10^{0}	3×10^{-1}	$3 \times 10^{+1}$	2×10^{0}	3×10^{-1}

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Table 5.14-4. Radiological Risks From Bounding Accident

Accident Scenario	*Baseline Case* Co-located Worker Risk (rem/yr)	*Baseline Case* Maximum Off-site Individual Risk (rem/yr)	*Baseline Case* Population Risk (LCF/yr)	*Closure Case* Co-located Worker Risk (rem/yr)	*Closure Case* Maximum Off-site Individual Risk (rem/yr)	*Closure Case* Population Risk (LCF/yr)
SNM Vault Fire	3.7E-7	1.1E-6	6.1E-7	3.7E-7	1.1E-6	6.1E-7
Pu Dock Fire - High-Am Residues	2.7E-5	2.2E-7	3.0E-8	1.1E-4	8.8E-7	1.2E-7
Waste Facility - 1 LLW Crate Fire	9.4E-2	7.7E-4	1.0E-4	9.4E-2	7.7E-4	1.0E-4
Waste Facility - 15 LLW Crate Fire	1.1E-4	3.1E-4	1.8E-4	1.1E-4	3.1E-4	1.8E-4
Waste Facility - TRU Drum Fire	2.3E-3	1.9E-5	2.5E-6	2.3E-3	1.9E-5	2.5E-6
Oxyacetylene Explosion in Pu Bldg.	1.0E-2	8.2E-5	1.1E-5	1.0E-2	8.2E-5	1.1E-5
Pu Dock Spill - Oxide	5.9E-3	4.8E-5	6.4E-6	2.4E-2	1.9E-4	2.6E-5
Pu Dock Spill - Residue Drum	2.1E-2	1.7E-4	2.3E-5	8.6E-2	7.0E-4	9.3E-5
Uranium Solution Criticality	4.2E-1	2.3E-3	4.2E-5	—	—	—
Plutonium Solution Criticality	3.4E-4	2.4E-6	1.2E-7	1.7E-0	2.4E-6	6E-4
Plutonium Oxide Criticality	7.5E-5	7.0E-7	3.0E-7	7.5E-5	7.0E-7	3.0E
Aircraft Crash	2.2E-7	6.4E-7	3.7E-7	2.2E-7	6.4E-7	3.7E-7
Seismic Collapse of Bldg. 371	2.3E-1	1.8E-3	2.5E-4	2.3E-1	1.8E-3	2.5E-4
Seismic Collapse of Bldg. 374	4.7E-4	3.8E-6	5.1E-7	4.7E-4	3.8E-5	5.1E-7
Seismic Collapse of Bldg. 559	3.9E-3	3.2E-5	4.3E-6	3.9E-3	3.2E-5	4.3E-6
Seismic Collapse of TRU Waste Storage Butler-type Buildings	3.7E-3	3.0E-5	4.0E-6	3.7E-3	3.0E-5	4.0E-6
Seismic Collapse of Building 707 Modules A through H	1.3E-1	1.0E-3	1.4E-4	7.0E-1	5.7E-3	7.6E-4
Seismic Collapse of Building 707 Modules J & K	3.2E-1	2.6E-3	3.5E-4	3.2E-1	2.6E-3	3.5E-4
Seismic Collapse of Bldg. 771/774	2.4E+0	1.9E-2	2.6E-3	2.4E+0	1.9E-2	2.6E-3
Seismic Collapse of Bldg. 776/777	1.8E+0	1.5E-2	2.0E-3	1.8E+0	1.5E-2	2.0E-3
Seismic Collapse of Bldg. 779	3.2E-2	2.6E-4	3.4E-5	3.2E-2	2.6E-4	3.4E-5
Seismic Collapse of Bldg. 991 TRU storage	1.4E-3	1.1E-5	1.5E-6	1.4E-3	1.1E-5	1.5E-6
High Winds	2.8E-3	2.3E-5	3.1E-5	2.8E-3	2.3E-5	3.1E-5
Composite Risk	5.5E+0	4.4E-2	5.8E-3	5.8E+0	4.7E-2	6.5E-3

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In order to discriminate between the accident risks posed under the various *baseline* and *closure* cases, the total annualized accident risks (probability of occurrence multiplied by the impacts of occurrence) from the combination of all of the individual accidents have been summed to yield an aggregate risk measure. This is a common approach to portray the relative accident impacts of the CID *baseline* and *closure* cases under consideration. It should be remembered that the activities described or delineated for each alternative determines the risk envelope.

For the *baseline* case, seismic events dominate risk to co-located workers and the public. This is due to the majority of the SNM and residue inventory being stored in buildings which are more vulnerable to earthquakes. In addition, the materials are not repackaged into more robust containment. As a result, a low probability, but high-consequence accident (such as an earthquake) would be expected to dominate the risks. In fact, the seismic events represent over 90% of the *baseline* case total risks to all receptors. Annualized excess latent cancer fatality risk to the maximally exposed co-located worker is estimated to be 5.5 rem CEDE per year (or 2 x 10^{-3} excess latent cancer fatality per year), and risk to the maximally exposed off-site individual is 0.044 mrem CEDE per year (or 2 x 10^{-5} excess latent cancer fatalities per year). The combined risk to the general population from all accidents evaluated is 0.0058 excess latent cancer fatality per year (or one excess latent fatal cancer in 170 years).

Figure 5.14-1 presented earlier illustrates the distribution of SNM residues, TRU wastes, and plutonium holdup by building. Approximately 60% of SNM has been consolidated into Building 371, which also stores approximately two-thirds of the residue inventory. This "lions-share" of Site inventory of radioactive materials is the reason why Building 371's releases from a seismic collapse dominates radiological consequence (e.g., 63% of dose to the maximally exposed off-site individual). However, due to B371's greater seismic strengths than the other plutonium buildings, it only contributes 5% to risks (i.e., a less likely probability of occurrences for a greater magnitude earthquake). Seismic risks to the public are dominated by residues in Buildings 771 and 776/777.

Table 5.14-5 shows the contribution by form of material to seismic risks for the *baseline* case. The most significant contribution is from residues (77% due to plutonium and americium concentrated by molten salt operations). The next significant contribution is plutonium oxide (24% with minor contributed from metals). This lesser contribution from oxide is due to continued SNM consolidation into Building 371, and the conservative assumption that much of the residues and americium are as dispersible as oxides. Then plutonium holdup in buildings contributes to seismic risks (8%). Lastly, TRU wastes contribute approximately 1% to seismic risks.

Closure Case. An illustration of the risk profile due to accidents over the full duration of the *closure* case is provided in Figure 5.14-2. This shows that there is a slight increase in risk in the near term as residue stabilization and repackaging activities are started in Building 707. Risks drop as Building 771 and 776 SNM and residues are eliminated. When the residues are repackaged and SNM is moved to the new Interim Storage Vault (ISV), risks from accidents decrease significantly (about a factor of 10), and then steadily decrease as plutonium holdup is removed during DD&D. The risk from fires involving LLW in wooden boxes then dominate risk until the year 2012 when all LLW and TRU waste shipments are completed, resulting in another three orders of magnitude reduction in risks from accidents. Accident risk to the public after this time is due to material handling in the new ISV until the SNM is shipped off-site by the year 2014.

The seismic risks for the *closure* case is about 10% higher because residue processing activities will be performed in B707. The risk to the co-located worker is 5.8 rem CEDE per year (2 x 10^{-3} LCF per year), and risk to the maximally exposed off-site individual is 0.047 mrem CEDE per year (2 x 10^{-5} LCF per year). The combined risk to the general population from all accidents evaluated is 0.0065 excess latent cancer fatality per year (one fatal cancer in 150 years). Once SNM in 3013 containers is consolidated into the new Interim Storage Vault (ISV) and high dispersible residues (ash, wet combustibles, and some salts) are repacked into more robust packages (pipe component/drum) then facility accident risks will be substantially less than the *baseline* case. Seismic risk would then be dominated by plutonium holdup until DD&D is substantially completed.

This is illustrated in Figure 5.14-3. This is because most of the hazardous materials are stored in robust containers and/or in the new hardened storage facility which is expected to release no or minimal amounts of radioactive material when severe earthquakes or external accident events occur. In addition, once materials are moved for storage into the ISV and new packages (pipe component/drum) are used for TRU/TRUM waste resulting from residue stabilization, site handling and transportation activities should decrease substantially - until the material is removed from interim storage at the Site - to permanent disposal facilities off-site.

The peak year during the *closure* case in terms of seismic risks is around the year 2000 when SNM and residue stabilization are both in full operation. However, seismic risks are still dominated by B707 and B776 due to oxide and residue storage as shown in Figure 5.14-4. Removal of the majority of dispersible material in B771 and B779 result in a much lower contribution from these two buildings. Although TRU waste storage facilities will have approximately 450 kg plutonium, most will be from residues repackaged into the pipe component/drum and thus their contribution is smaller.

Figure 5.14-5 shows the expected distribution of radioactive materials and contributions to accidental risks after FY 2004 when SNM and residue stabilization and repackaging activities are completed. The alternative residue rebaseline strategy described in Table 3-3 would achieve the same level of risk reduction since any recovered Pu oxide would be stored in the new ISV. At this time, accident risks are still dominated by holdup in Buildings 707, 771, and 776/777, and from TRU waste storage buildings.

After plutonium holdup is eliminated, risk will be dominated by fires involving LLW in wooden crates. This is due to a higher release fraction for unconfined combustible materials and the protection afforded by steel drums for TRU wastes or the residue pipe component/drum.

After all TRU and LL wastes are shipped off-site, risks from accidents would be associated with material handling in the SNM ISV.

Figure 5.14-6 illustrates how the *closure* case greatly reduces the Site seismic risks by approximately four to five orders of magnitude to near zero in the year 2013. This is due to construction of the new Interim Storage Vault for SNM storage, the protection provided by the pipe component/drum for residues, continued off-site shipping of TRU and LL wastes, and the DD&D of plutonium facilities.

5.14.2 Chemical Accident Analysis

The primary mission of the Site has been to shape components from plutonium and other metals for the Department of Energy. Plant operations once involved fabrication and recovery of plutonium; waste treatment, storage, and shipment for off-site disposal; operating several chemical laboratories; and performing research and development. Because of the wide variety of operations that have been conducted at the Site, the amounts and concentrations of the chemicals used varied widely. In most cases, the quantities were small and in dilute form; however, in some operations, the chemicals were used in large quantities and/or in high concentrations. Now due to limited Site operations, the inventory of chemicals has been substantially reduced from earlier levels. Nonetheless, substantial amounts of ammonia, chlorine, sulfur dioxide, nitric acid, sulfuric acid, and propane are maintained at the Site. A potential of releasing these chemicals into the environment exists due to equipment failure, operator error, transportation activities, or natural disasters, such as earthquakes. These situations, if they were to occur, would be considered accident scenarios.

This section addresses the chemical (toxic and flammable substances) accident scenarios postulated for the Site and summarizes the potential health effects associated with a release from the identified scenarios. The Site chemical accident scenarios addressed are:

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Table 5.14-5 Overall Site Risk For "Baseline Case" From Seismic Collapse (Bounding Accident)

Inventory	Pu Metal & Oxide	Residues	Pu Holdup	TRU/TRUM Wastes	Americium	Seismic Risk	Other Contributors	Site Risk
Public Risk (MO I - Rem/Yr)	9×10^{-3}	1.5×10^{-2}	3×10^{-3}	4×10^{-4}	1.1×10^{-2}	3.9×10^{-2}	4×10^{-3}	4.3×10^{-2}
Public Risk (50 mi Population - LCF/Yr)	1.3×10^{-3}	2×10^{-3}	4×10^{-4}	5×10^{-5}	1.5×10^{-3}	5.3×10^{-3}	2×10^{-4}	5.5×10^{-3}
Collocated Worker (Rem/Yr)	1.2	1.8	0.4	0.05	1.4	4.8	0.5	5.3
% Contribution	24%	38%	8%	1%	29%	100%		

Figure 5.14-2 Public Risk Profile Due to Accidents

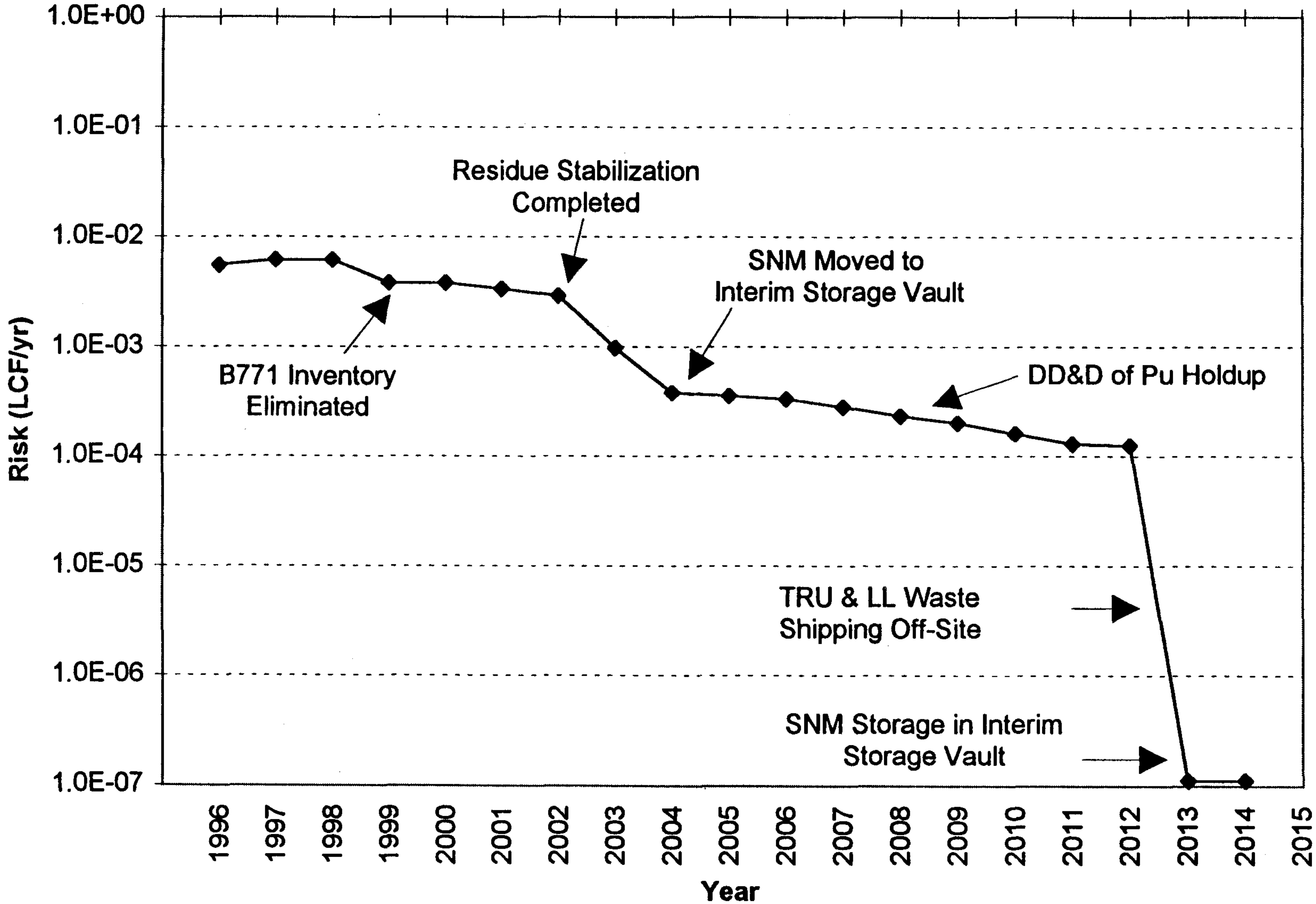

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Figure 5.14-3 Public Risk Profile

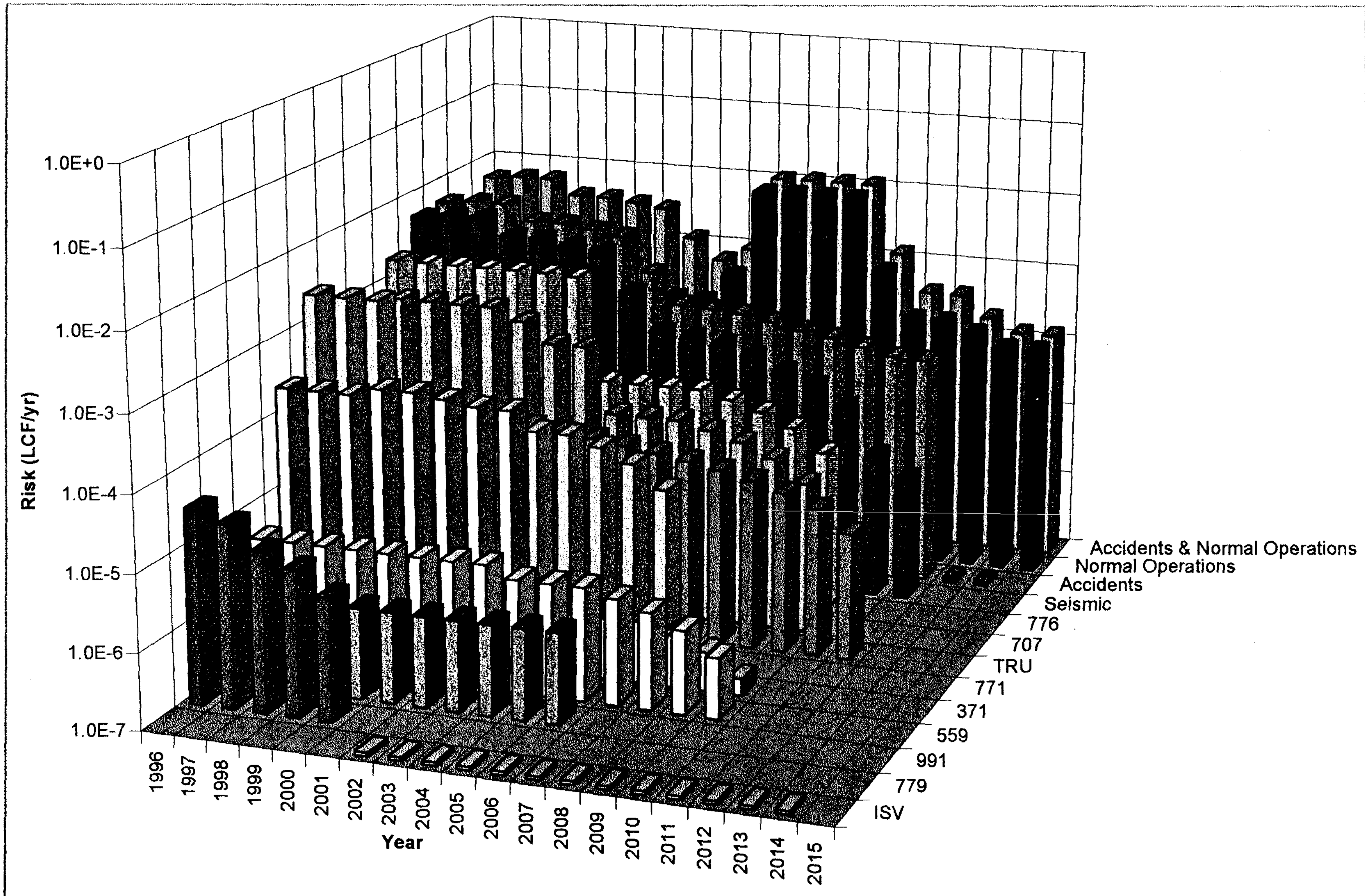

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Figure 5.14-4 Closure Case: Inventory and Public Risk During Peak Residue Stabilization (Around Year 2000)

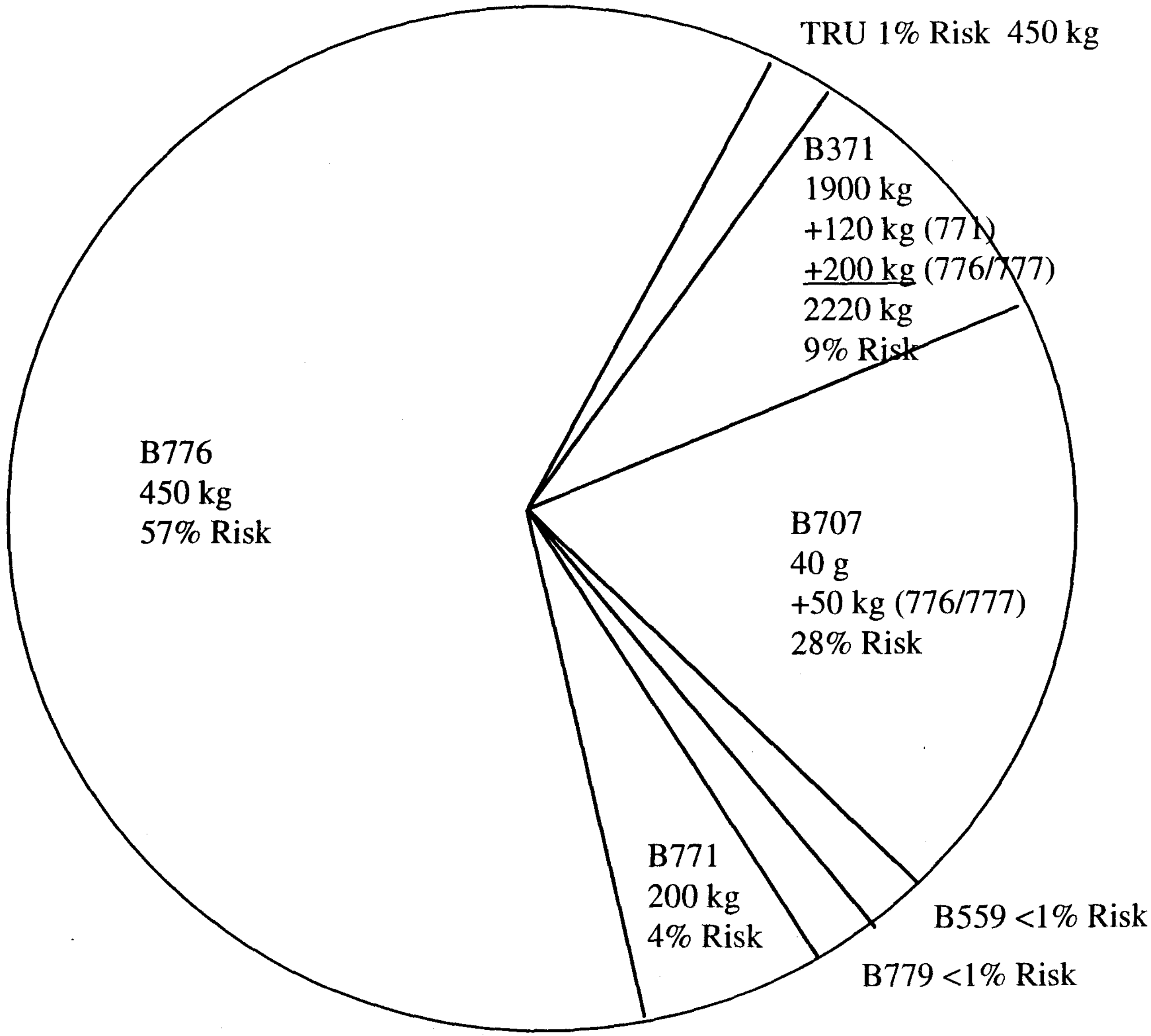


Figure 5.14-5 Closure Case Profile/Contribution To Seismic Risk By Building After FY04 SNM Consolidated, Residues Stabilized/Repackaged (Rev. 5.0), Uranium Shipped Off-Site

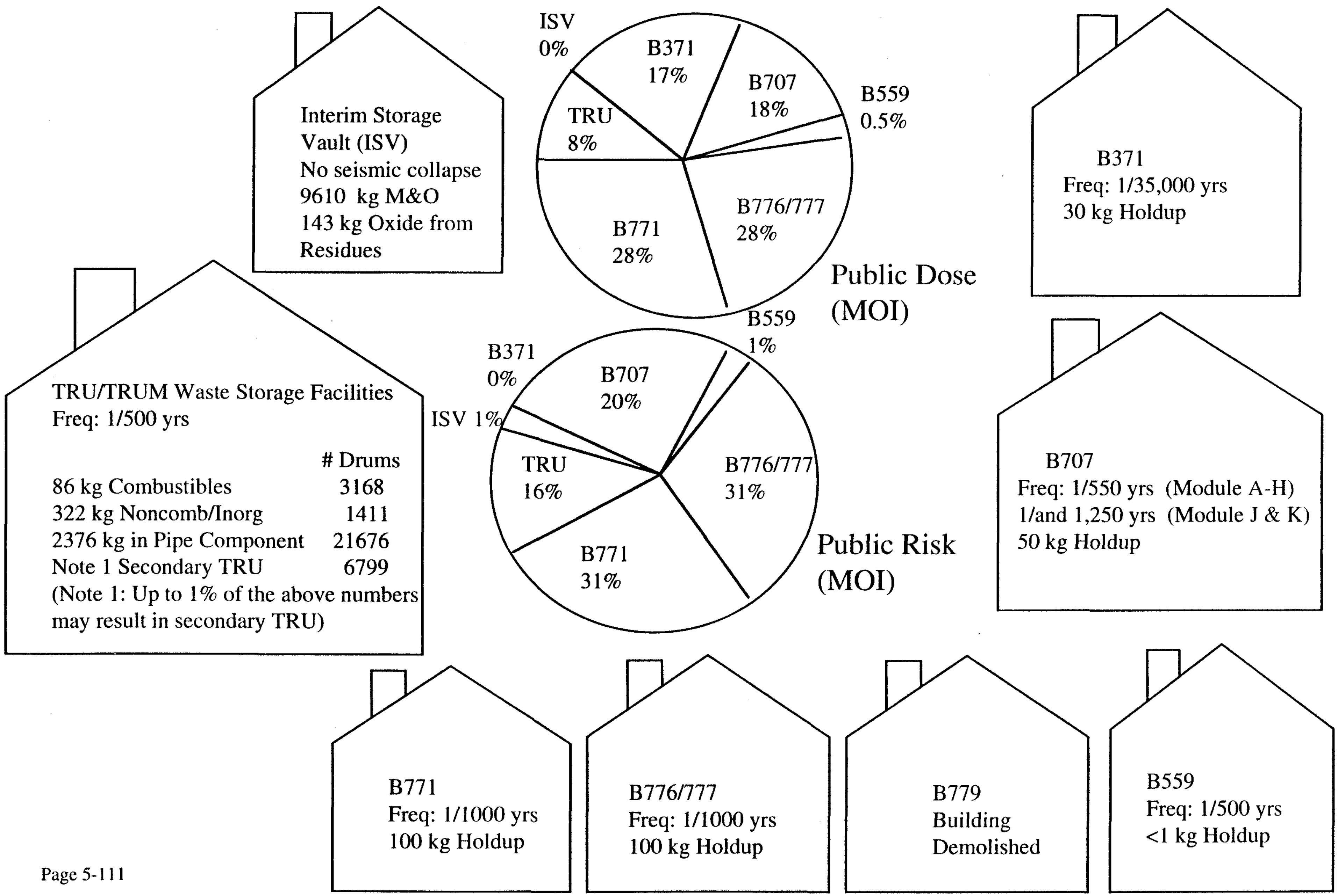
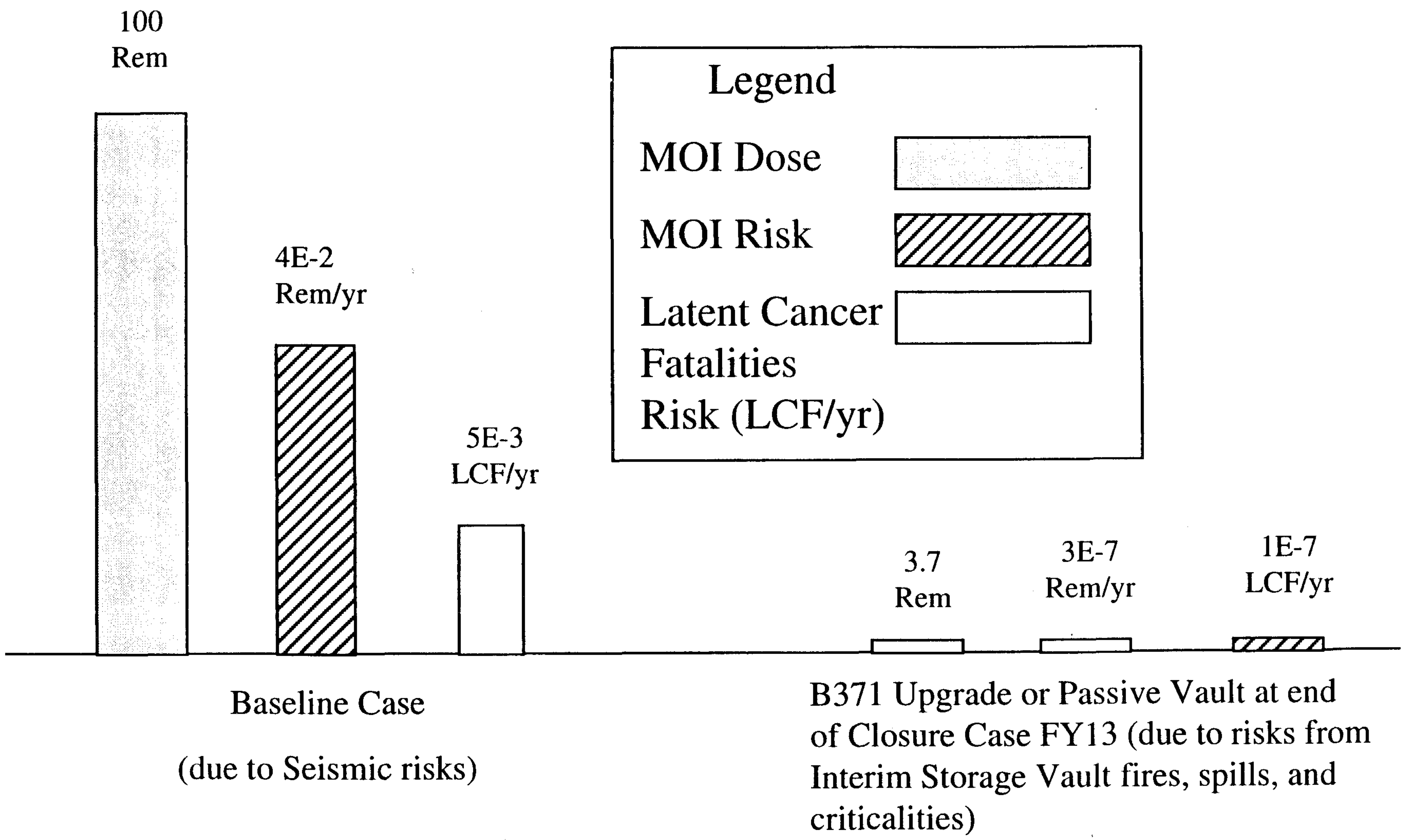


Figure 5.14-6 Closure Case will Greatly Reduce Site Accident Risk to Near Zero



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TOXIC SUBSTANCE RELEASES:

- A release of one-150 pound cylinder of ammonia from Building 881;
- A release of two-150 pound cylinders of chlorine from Building 995, part of the Site Waste Water Treatment Plant (WWTP);
- A release of two-150 pound cylinders of sulfur dioxide from Building 995;
- A release of 90,000 pounds of a nitric acid mixture (56% nitric acid by weight) from the outside storage tank (D222) at the Building 371/374 Complex; and

FLAMMABLE SUBSTANCE RELEASE:

- A propane release and subsequent unconfined vapor cloud explosion (UVCE) at the P705 or the P904 propane tank farms. Each tank farm contains eight-1,000 gallons tanks interconnected to a common manifold.

Postulated releases of the additional chemicals stored on-site may occur; however, they are considered to have lesser impact to the public and co-located worker than the release scenarios postulated here.

Chemical Accident Analysis Screening Methodology

Accidents involving ammonia, chlorine, sulfur dioxide, and nitric acid were considered to be inadvertent releases of toxic substances from confinement to the environment resulting in physical injury or property damage. The accident involving propane was considered to be a release of a flammable substance and subsequent UVCE that could cause injury to personnel or damage to nearby structures due to explosion overpressure effects. Postulated accidents included events which could result from external initiators (e.g., vehicle crashes, explosions, etc.), internal initiators (e.g., equipment failures, human error, etc.), and natural phenomena initiators (e.g., earthquakes, tornadoes, etc.). A discussion of the chemical accident analysis screening methodology is provided below. Details of the accident analysis evaluation methodology are provided in Appendix C-6 "Chemical Accidents."

TOXIC SUBSTANCE RELEASES: Information involving the use of toxic substances was reviewed to identify those chemicals with a potential for on-site/off-site releases to Site workers and the general public. In general, the methodology used to screen the chemicals included: 1) identifying toxic chemicals present in quantities exceeding the threshold planning quantities (TPQs) listed in 40 CFR Part 355 (SARA Title III requires emergency planning and reporting for the extremely hazardous substances present in excess of the threshold planning quantities) or the threshold quantities (TQs) listed in 40 CFR Part 68, Accidental Release Prevention Requirements: Risk Management Programs; 2) modeling a credible release of the identified toxic chemicals to the atmosphere to determine airborne concentrations at the receptor locations; and 3) comparing those airborne concentrations to the Emergency Response Planning Guideline (ERPG) values. Upon determining the chemicals that represent realistic accident consequences, exposure assessments for the identified receptors were conducted and dose assessments based on the postulated exposures were developed.

FLAMMABLE SUBSTANCE RELEASE: Information involving the use of flammable substances was reviewed to identify those chemicals with a potential for on-site/off-site impact to Site workers and the general public. In general, the methodology used to screen the chemicals included: 1) identifying flammable chemicals present in quantities exceeding the threshold quantities (TQs) listed in 40 CFR Part 68 or 29 CFR 1910.119, Process Safety Management of Highly Hazardous Chemicals, and 2) modeling a credible release and subsequent unconfined vapor cloud explosion (UVCE) as a worst-case scenario. Upon determining the chemical(s) that represent realistic accident consequences, an exposure assessment for the identified receptors was conducted and injury/damage assessments based on the postulated exposures were developed.

Health Effects Endpoints

Potential exposure to toxic substances involves the dispersion and migration of the plume to receptor locations. An exposure endpoint is a quantifiable threshold at which a level of health effects or property damage may occur. The exposure endpoint is used to estimate the distance at which a certain level of health effect or damage may be reached. For toxic substances, the primary exposure hazard to the public is inhalation of vapor.

The consequences under consideration are the immediate health effects expected from a one-time acute exposure to a chemical resulting from an accidental release; rather than the potential consequences of long-term chronic exposure resulting from continuous releases. Ammonia, chlorine, sulfur dioxide, and nitric acid are not listed as potential carcinogens, and long-term cancer latency rate calculations are not applicable. Hazardous materials can pose toxic effects via three primary pathways of exposure: inhalation, ingestion, or direct contact with the skin or eyes. The exposure pathway of concern for this analysis is inhalation, which is the most sensitive route of exposure for individuals exposed to airborne substances. Appendix C-6 "Chemical Accidents" discusses the computer models applied for the dispersion analysis (e.g., ALOHA for hazardous air releases and ARCHIE for flammable gases).

EMERGENCY RESPONSE PLANNING GUIDELINES. The consequences from accidental releases are estimated based upon airborne concentrations at various distances (receptor locations) from the accident location. This assessment includes the use of Emergency Response Planning Guidelines (ERPGs) to provide estimates of concentration ranges where one might reasonably expect to observe adverse effects from exposure to specific substances. The values derived for ERPGs are used for emergency planning purposes and are applicable to most individuals in the general population. The ERPG values are not regulatory exposure guidelines and do not incorporate the safety factors normally included in healthy worker exposure guidelines.

The ERPGs were developed by the American Industrial Hygiene Association to aid emergency planners and emergency responders in dealing with hazardous materials incidents (AIHA 1996). Additional information on ERPG values is provided in Figures 5.14-7 and 5.14-8.

Receptor Descriptions

The chemical accident analysis assessed the effects of an accidental release of toxic substances on three receptor groups. This allowed exposure estimates at various distances from the accident location. These receptor groups are defined as:

- Immediate Workers–an individual at 30 meters from the point of release assumed to be working at or within 30 meters of point of release. The immediate worker is assumed not to be wearing personal protective equipment, however, is expected to evacuate the accident scene;

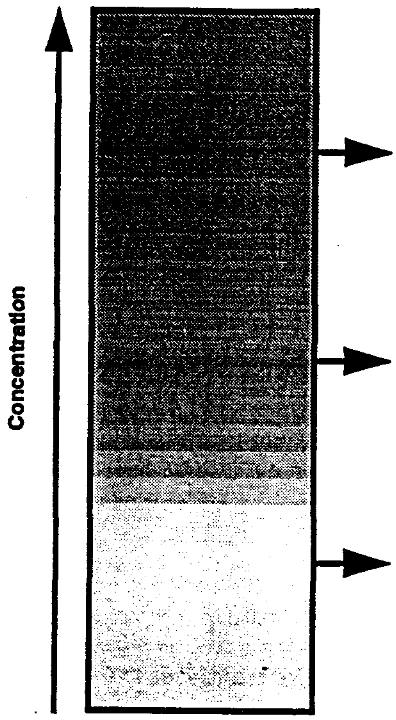
- Co-located Workers–exposure assessments for co-located workers were conducted at 100 meters (328 feet) from the postulated point of release. Co-located workers are assumed not to be wearing personal protective equipment;

- Maximally Exposed Off-site Individuals (MOI) of the Public–a hypothetical member of the public who is located off-site at the nearest point of access to the point of release who would receive the largest exposure from a release.

In addition to these receptor locations, the distance to the ERPG concentrations were determined and presented to show the maximum distance at which individuals may be impacted.

For the propane release scenario, the receptor location is the distance to the endpoint at which personnel injury and damage to buildings could occur. The distance at which these effects occur is the distance to a one psig overpressure due to blast and shock waves.

Figure 5.14-7 Emergency Response Planning Guidelines (ERPG)



Chlorine

ERPG-3: (Life Threatening) 20 ppm

The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.

ERPG-2: (Irreversible) 3 ppm

The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or serious health effects or symptoms that could impair an individual's ability to take protective action.

ERPG-1: (Reversible) 1 ppm

The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing other than mild, transient adverse health effects or without perceiving a clearly defined objectionable odor.

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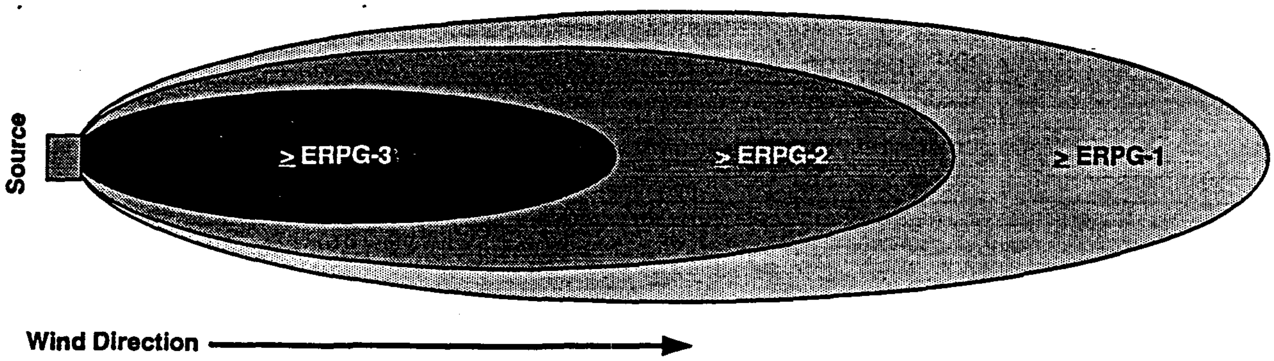
Figure 5.14-8 Example Chemical Plume and Concentration Levels



A chemical plume emitted from a finite source decreases in concentration as the chemical is carried away from the source and dispersed by the wind.

Note: Chemical concentrations represented by shaded areas are greater than or equal to the indicated ERPG level.

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Accident Scenario Descriptions

The chemical accident scenarios addressed are: (1) an ammonia release from one-150 pound cylinder, (2) a chlorine release from 2-150 pound cylinders, (3) a sulfur dioxide release from two-150 pound cylinders, (4) a nitric acid (56% by weight) release from an above ground storage tank, and (5) a propane release from a 1,000 gallon propane tank and subsequent UVCE. The postulated chemical accident scenarios are discussed below and present in Table 5.14-6.

AMMONIA RELEASE: Building 881, a manufacturing and general support facility, utilizes ammonia in various rooms throughout the building. Each location has a single cylinder that may be uncapped to facilitate usage. A single cylinder is postulated to experience a failure (e.g., direct puncture, failure of the discharge valve, failure of piping/manifold, failure of the storage racks, piping failure, etc.) resulting in the release of the entire contents. This scenario results in the release of 150 pounds of ammonia from Building 881.

CHLORINE RELEASE: Building 995, part of the Waste Water Treatment Plant (WWTP), utilizes two 150 pound chlorine cylinders connected by an automatic switch over valve at the process location where the gas is drawn for the chlorinating process. Both cylinders are postulated to experience a failure (e.g., direct puncture, failure of the discharge valve, failure of the switch over valve, failure of piping/manifold, failure of the storage racks, piping failure, etc.) resulting in the release of their entire contents. This scenario results in the release of 300 pounds of chlorine from Building 995.

SULFUR DIOXIDE RELEASE: Sulfur dioxide is also utilized in the Building 995 waste water treatment processes. Two 150 pound cylinders of sulfur dioxide are connected by an automatic switch over valve at the process location where the gas is drawn into the process to remove chlorine. Both cylinders are postulated to experience a failure (e.g., direct puncture by structural debris, failure of the discharge valve, failure of piping/manifold, failure of the storage racks, foundation collapse, piping failure, etc.) resulting in the release of their entire contents. This scenario results in the release of 300 pounds of sulfur dioxide from Building 995.

NITRIC ACID RELEASE: The Building 371/374 outside nitric acid storage tank (designated as Tank D222) is postulated to experience a catastrophic failure. This scenario would result in a worst-case release of the entire contents of the tank, approximately 8,000 gallons of 56% by weight nitric acid solution into a bermed area around the tank. The berm around the tank is considered a passive mitigation feature and is credited in the analysis.

PROPANE RELEASE: The propane tank farms designated as P750 and P904 each contain eight-1,000 gallon propane tanks interconnected to a common manifold. For this release scenario it is postulated that one of the eight tanks catastrophically fails resulting in the release of 4,100 pounds of propane. The propane gas subsequently mixes with ambient air to form a vapor cloud that is in the flammable range within at least a portion of its volume. Ignition of the flammable mixture occurs with flame propagation through the flammable region of the cloud resulting in an overpressure condition.

Material Characterization and Inventory Assumptions

The toxicity/health hazards associated with inhalation of ammonia, chlorine, sulfur dioxide, nitric acid, and propane are described here to support development of accident scenarios and analysis of possible consequences.

AMMONIA (CAS: 7664-41-7). Ammonia is a colorless gas with a penetrating, suffocating odor. It causes extreme irritation of the bronchial tissues when inhaled; continued inhalation destroys respiratory tissue, which causes respiratory and pulmonary diseases. Elevated blood ammonia concentrations may cause death by suffocation. Ammonia is detectable by odor at 5-10 ppm; results in general discomfort, eye tearing, and irritation of mucous membranes at 150-200 ppm, and is barely tolerable (danger of lung edema, asphyxia, and death within minutes) for more than a

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few moments, at concentrations of 2,000 ppm. Properties of ammonia are provided in Appendix C-6 "Chemical Accidents."

Table 5.14-6. Chemical Accident Scenarios Chosen for Analysis

Release Scenario	Facility	Scenario Description
NH_3-01	Building 881	Release of 150 lb. of ammonia (from one-150 pound cylinder) resulting from mechanical failure or physical damage to a cylinder under **worst** case meteorological conditions.
NH_3-02	Building 881	Release of 150 lb. of ammonia (from one-150 pound cylinder) resulting from mechanical failure or physical damage to a cylinder under **average** meteorological conditions.
C1-01	Building 995	Release of 300 lb. of chlorine (from two-150 pound cylinders) resulting from mechanical failure or physical damage to a cylinder under **worst** case meteorological conditions.
C1-02	Building 995	Release of 300 lb. of chlorine (from two-150 pound cylinders) resulting from mechanical failure or physical damage to a cylinder under **average** case meteorological conditions.
SO_2-01	Building 995	Release of 300 lb. of sulfur dioxide (from two-150 pound cylinders) resulting from mechanical failure or physical damage to a cylinder under **worst** case meteorological conditions.
SO_2-02	Building 995	Release of 300 lb. of sulfur dioxide (from two-150 pound cylinders) resulting from mechanical failure or physical damage to a cylinder under **worst** case meteorological conditions.
HNO_3-01	Building 371/374 Complex	Release of 90,000 lb. of 56% by weight nitric acid resulting from a catastrophic failure of the outside nitric acid storage tank (D222) under **worst** case meteorological conditions.
HNO_3-02	Building 371/374 Complex	Release of 90,000 lb. of 56% by weight nitric acid resulting from a catastrophic failure of the outside nitric acid storage tank (D222) under **average** case meteorological conditions.
Propane-01	P750/P904	Release of 4,100 pound of propane from a single 1,000 gallon tank at either the P750 or P904 propane tank farm and subsequent UVCE.

CHLORINE (CAS: 7782-50-5). Chlorine is a greenish-yellow, nonflammable gas that is toxic to humans by inhalation. Chlorine is not listen in the EPA Integrated Risk Information System (EPA 1995c) or the Health Effects Assessment Summary Tables (EPA 1995b) as a potential carcinogen. Human respiratory system effects by inhalation include changes in the trachea or bronchi, emphysema, chronic pulmonary edema, or congestion. Chlorine is a strong irritant to eyes and mucous membranes at 3 ppm. Chlorine combines with moisture to form hydrochloric acid. Both of these substances, if present in sufficient quantities, cause inflammation of the tissues with which they contact. A concentration of 3.5 ppm produces a detectable odor. A concentration to 15 ppm causes immediate irritations of the throat. Concentrations of 50 ppm are dangerous for even short periods of time, and concentrations of 1,035 ppm may be fatal (NIOSH 1991), even if the exposure is brief. Some studies indicate that some fatalities may result from a 30-minute exposure to 50-60 ppm. Because of its intensely irritating properties, severe industrial exposure seldom occurs, as the worker is forced to leave the exposure area before being seriously affected. Chlorine is a strong oxidizer and reacts with numerous other chemicals and metals and may cause explosive reactions. Properties of chlorine are provided in Appendix C-6 "Chemical Accidents." Chlorine is a heavier than air gas.

SULFUR DIOXIDE (CAS: 7446-09-5). Sulfur dioxide is a poisonous gas that is mildly toxic to humans by inhalation. Human systemic effects by inhalation include: pulmonary vascular resistance, respiratory depression and other pulmonary changes. It affects the upper respiratory tract and the bronchi. It may cause edema of the lungs or glottis, and can produce respiratory paralysis. A corrosive irritant to eyes, skin, and mucous membranes. This material is so irritating that it provides its own warning of toxic concentration. At 400-500 ppm it is immediately dangerous to life. A concentration between 50-100 ppm is considered to be the maximum permissible concentration for exposures of 30-60 minutes. Excessive exposures to high concentrations of sulfur dioxide can be fatal. However, less than fatal concentrations can be borne for fair periods of time with no apparent permanent damage. Properties of sulfur dioxide are provided in Appendix C-6 "Chemical Accidents." Sulfur dioxide is a heavier than air gas.

NITRIC ACID (CAS: 7697-37-2).
Pure nitric acid is a colorless liquid. When commonly encountered, however, it is often yellow to red-brown in color, depending on the concentration of dissolved nitrogen dioxide. Nitric acid corrodes body tissue by reacting with complex proteins that make up the structure of tissues. Inhalation of vapors may cause nausea, vomiting, lightheadedness, head ache, severe irritation of the respiratory system, coughing, chest pains, difficulty breathing, or unconsciousness. Properties of nitric acid are provided in Appendix C-6 "Chemical Accidents."

PROPANE (CAS: 74-98-6).
At ambient conditions, propane is a colorless, odorless (may have odor added), and tasteless gas, but under moderate pressure, it is readily liquefied. Propane is a highly dangerous fire hazard when exposed to heat or flame and can react vigorously with oxidizers. It is explosive in the form of vapor when exposed to heat or flame. Propane can affect the central nervous system at high concentrations (the IDLH is 20,000 ppm) and is considered an asphyxiant. Properties of propane are provided in Appendix C-6 "Chemical Accidents."

INVENTORY ASSUMPTIONS. Information relating to the types and quantities of chemicals stored on-site and storage locations was obtained from the Site Facility Profile and Internal Contingency Plan (EG&G 1995k) and the site ICMS database. Table 5.14-7 presents a list of ammonia, chlorine, sulfur dioxide, nitric acid, and propane inventories and storage locations.

Analysis of the ammonia, chlorine, and sulfur dioxide releases were conducted considering the greatest amount held in a single vessel or held in multiple vessels that are interconnected. For ammonia, the release amount was assumed to be 150 pounds, in a single "active" cylinder. For chlorine and sulfur dioxide, the release amount was assumed to be 300 pounds in two "active" 150 pound cylinders interconnected to a common manifold.

Analysis of the nitric acid release was conducted assuming the greatest amount held in a single vessel. The largest vessel containing nitric acid was determined to be Tank D222 outside the Building 371/374 Complex. The capacity of this tank is 16,000 gallons, however, the current inventory is approximately 50% or 8,000 gallons. The inventory in the tank will be administratively controlled not to exceed 50% capacity.

Analysis of the propane explosion was conducted by considering the greatest amount held in a single vessel within the tank farms which is consistent with the 40 CFR 68 hazard assessment methodology for flammable substances.

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Table 5.14-7. Inventories Involved in Postulated Release Scenarios

Hazardous Substance	Initiating Event	Inventory	Location
Ammonia	Cylinder failure due to mechanical failure or physical damage	150 lb.	Building 881
Chlorine Gas	Cylinder failure due to mechanical failure or physical damage	300 lb.	Building 995
Sulfur Dioxide	Cylinder failure due to mechanical failure or physical damage	300 lb.	Building 995
Nitric Acid Mixture	Catastrophic tank failure	90,000 lb.	Outside Building 371/374 Complex
Propane	Catastrophic tank failure	4,100 lb.	Tank Farms P750 and P904

Estimated Impacts - Toxic Releases

This section describes the potential health consequences of the ammonia, chlorine, sulfur dioxide, and nitric acid accident scenarios. The results are presented in terms of the three ERPG concentrations, at distances to the receptors identified previously. The exposures were determined separately for each postulated accident scenario. During accident conditions, no specific wind direction was selected so that 100% of the released material was conveyed to all potential receptors regardless of direction from the release point. In all cases, evacuation of personnel per emergency response procedures will reduce the exposure duration and, therefore, the potential health impacts described in subsequent paragraphs of this section. Table 5.14-8 presents a listing of impacts to identified receptors by release scenario.

IMPACTS TO IMMEDIATE WORKERS. Immediate workers are assumed to be working at or within 30 meters of the point of release. The concentrations of ammonia at 30 meters range from 4,980 to 8,110 ppm based on the assumed meteorological conditions. These concentrations exceed the ERPG-3 endpoint of 1,000 ppm and are potentially life threatening to the immediate worker.

Death from exposure to chlorine has been reported following a five-minute exposure to chlorine concentrations of 1,035 ppm (NIOSH 1991). While the immediate worker may be assumed to be among the fatalities resulting from the initiating event, concentrations of chlorine at 30 meters range from 1,730 to 3,440 ppm based on the assumed meteorological conditions. These concentrations exceed the ERPG-3 endpoint of 20 ppm and are potentially life threatening to the immediate worker.

For the sulfur dioxide release scenario, the concentrations at 30 meters range from 1,830 to 3,650 ppm based on the assumed meteorological conditions. These concentrations exceed the ERPG-3 endpoint of 15 ppm and are potentially life threatening to the immediate worker.

For the nitric acid release scenario, the concentrations at 30 meters range from 46 to 141 ppm based on the assumed meteorological conditions. These concentrations exceed the ERPG-3 endpoint of 30 ppm and are potentially life threatening to the immediate worker.

IMPACTS TO CO-LOCATED WORKERS. Co-located workers are assumed to be 100 meters from the point of release. The concentrations of ammonia at 100 meters range from 548 to 990 ppm based on the assumed meteorological conditions. These concentrations exceed the ERPG-2 endpoint of 200 ppm and present potentially irreversible health effects to the co-located worker. The actual distances to the ERPG-2 toxic endpoint are either 170 meters or 282 meters depending on the

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assumed meteorological conditions. Based upon the distances to the ERPG-2 endpoint, workers located beyond the 100 meter distance could also suffer irreversible health effects.

The concentrations of chlorine at 100 meters from the point of release range from 235 to 376 ppm based on the assumed meteorological conditions. These concentrations exceed the ERPG-3 endpoint of 20 ppm and are potentially life threatening to the co-located worker. The actual distances to the ERPG-3 toxic endpoint are 394 meters or 664 meters depending on the assumed meteorological conditions. Based upon the distances to the ERPG-3 endpoint, workers located beyond the 100 meter distance could also be exposed to life threatening concentrations of chlorine.

For the sulfur dioxide release scenario, the concentrations at 100 meters range from 276 to 405 ppm based on assumed meteorological conditions. These concentrations exceed the ERPG-3 endpoint of 15 ppm and are potentially life threatening to the co-located worker. The actual distances to the ERPG-3 endpoint are 480 meters or 847 meters depending on the assumed meteorological conditions. Based upon the distances to the ERPG-3 endpoint, workers located beyond the 100 meter distance could also be exposed to life threatening concentrations of sulfur dioxide.

For the nitric acid release scenario, the concentrations range from 4 to 18 ppm based on the assumed meteorological conditions. The 18 ppm concentration exceeds the ERPG-2 concentration of 15 ppm and presents potentially irreversible health effects. The 4 ppm concentration exceeds the ERPG-1 concentration of 2 ppm and presents potentially reversible health effects.

IMPACTS TO MAXIMALLY EXPOSED OFF-SITE INDIVIDUALS OF THE PUBLIC. The Maximally Exposed Off-site (MOI) Individual of the Public is assumed to be located at the nearest off-site location from the point of release. The MOI distance is 1,788 meters from Building 881 for the ammonia release; 2,242 meters from Building 995, for the chlorine and sulfur dioxide releases; and 1,580 meters from Building 371/374 Complex, for the nitric acid release.

For the ammonia release scenario, the MOI would potentially be exposed to concentrations less than the ERPG-1 endpoint of 25 ppm (regardless of the assumed meteorological conditions) resulting in only mild health effects.

For the chlorine release scenario, the MOI would potentially be exposed to concentrations that range from 0.7 to 3.1 ppm based on assumed meteorological conditions. The 3.1 ppm concentration barely exceeds the ERPG-2 endpoint of 3 ppm and presents potentially irreversible health effects. The 0.7 ppm concentration is less than the ERPG-1 endpoint of one ppm and presents only mild health effects.

For the sulfur dioxide release scenario, the MOI would be potentially exposed to concentrations that range from 0.8 to 3.3 ppm based on assumed meteorological conditions. The 3.3 ppm concentration exceeds the ERPG-2 endpoint of 3 ppm and presents potentially irreversible health effects. The 0.8 ppm concentration exceeds the ERPG-1 endpoint of 0.3 ppm and presents potentially reversible health effects.

For the nitric acid scenario, the MOI would potentially be exposed to concentrations less than the ERPG-1 endpoint of 2 ppm (regardless of the assumed meteorological conditions) resulting in only mild health effects.

CHEMICAL RELEASE RISKS. As stated above, the potential consequences to the public range from mild to irreversible health effects if effective emergency response actions are not implemented. The likelihood and risks of these accidents were not assessed. If the similar risk assessment methodology that was applied to evaluating off-site transportation accidents involving chemicals were applied, it is expected that the risk from chemical accidents would be low. The Site's emergency preparedness program specifically addresses hazardous chemicals.

Table 5.14-8 Estimated Impacts for Toxic Substance Releases

		150 lb. NH_3 (worst case meteorology)	150 lb. NH_3 (average meteorology)	300 lb. Cl (worst case meteorology)	300 lb. Cl (average meteorology)	300 lb. SO_2 (worst case meteorology)	300 lb. SO_2 (average meteorology)	50,000 lb. HNO_3 (worst case meteorology)	50,000 lb. HNO_3 (average meteorology)
Maximum Distance To:	ERPG-1	1.1 km	516 m	3.9 km	1.9 km	6.6 km	3.7 km	338 m	145 m
	ERPG-2	282 m	170	2.3 km	1.1 km	2.3 km	1.1 km	111 m	53 m
	ERPG-3	99 m	72 m	661 m	386 m	847 m	480 m	76 m	36 m
Maximum Consequences									
Immediate Worker (30 m)	Parts per million (ppm)	8,110	4,980	3,440	1,730	3,650	1,830	141	46
	Level of Concern	> ERPG-3	> ERPG-3	> ERPG-3	> ERPG-3	> ERPG-3	> ERPG-3	> ERPG-3	> ERPG-3
	Potential Health Effects	Life Threatening	Life Threatening	Life Threatening	Life Threatening	Life Threatening	Life Threatening	Life Threatening	Life Threatening
Co-located Worker (100 m)	Parts per million (ppm)	990	548	376	235	405	276	18	4.2
	Level of Concern	> ERPG-3	> ERPG-3	> ERPG-3	> ERPG-3	> ERPG-3	> ERPG-3	> ERPG-3	> ERPG-3
	Hazard Quotient	40	22	376	235	1350	920	9	2.1
	Potential Health Effects	Irreversible	Irreversible	Life Threatening	Life Threatening	Life Threatening	Life Threatening	Irreversible	Reversible
Maximally Exposed Off-site Individuals [1]	Parts per million (ppm)	11	2.4	3.1	0.7	3.3	0.8	0.1	0.02
	Level of Concern	> ERPG-2	> ERPG-2	> ERPG-2	> ERPG-2	> ERPG-2	> ERPG-2	> ERPG-2	> ERPG-2
	Hazard Quotient	0.4	0.1	3.1	0.7	11	2.7	0.05	0.01
	Potential Health Effects	Mild	Mild	Irreversible	Mild	Irreversible	Reversible	Mild	Mild

[1] The MOI distances are as follows: 1,788 meters for the ammonia scenario, 2,242 meters for chlorine and sulfur dioxide scenarios, and 1,580 meters for the nitric acid scenario.

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Estimated Impacts - Propane Release/UVCE

This section describes the potential effects of an UVCE of propane. The distance to a one psig overpressure, which could result in surrounding building damage and injury to personnel, is 136 meters. There are three nuclear facilities, two radiological facilities, and four industrial facilities/areas located within a 136 meter radius of the P750 or P904 propane tank farm locations. These facilities are listed below:

- The 750 Pad, Storage Pad - Pondcrete, classified as a Category 3 Nuclear Facility.
- The 750 Trailer Area, Office Trailers, Classified as Industrial Facilities.
- Building 765, Secondary Alarm Center, classified as an Industrial Facility.
- Building 903A, Main Decontamination Facility, classified as a Radiological Facility.
- Building 903B, Decontamination Support Facility, classified as an Industrial Facility.
- Building 892, RCRA Storage Unit 18.04, classified as a Radiological Facility.
- The 903 Pad, Radiological Pad, classified as a Category 3 Nuclear Facility.
- Building 906, Centralized Waste Storage, classified as a Category 3 Nuclear Facility.
- The 891 Trailer Area, Offices Trailers, classified as Industrial Facilities.

A radiological material release from any of the Category 3 Nuclear Facilities within the 136 meter radius, due to an UVCE of propane, are bounded by accident scenarios analyzed in Section 5.14.1, "Radiological Accidents." For the radiological facilities, the radiological material-at-risk (MAR) is assumed to be below quantities that would present unacceptable consequences to the co-located worker or public if released. Personnel injury could potentially occur at each of the locations within the 136 meter radius. Table 5.14-9 summarizes the UVCE effects.

Table 5.14-9. Propane Unconfined Vapor Cloud Explosion Effects

Overpressure (psig)	Distance From Explosion (m)	Expected Damage
.03	2,589	Occasional breakage of large windows under stress.
.30	365	Some damage to home ceilings; 10% window breakage.
1.0 (Explosion Endpoint)	**136**	**Partial demolition of homes, made uninhabitable, knocks individuals off their feet.**
2.0	82	Partial collapse of home walls/roofs.
2.5	71	50% destruction of home brickwork.
5.0	46	Wooden utility poles snapped.
10	31	Probable total building destruction.

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Chemical Impacts - *Closure* Case

This section addresses the effects of the postulated accident scenarios as they would change during the *closure* case timeframe.

Chlorine and sulfur dioxide usage in Building 995 is expected to be eliminated by the end of 1997 thus eliminating the potential release scenarios from this Building. The only other building that utilizes chlorine in a process is Building 124 at the Water Treatment Plant. One cylinder is active in the process at a given time with additional cylinders staged in storage (in an approved storage rack, chained, with valve caps in place). Therefore, the chlorine release scenario becomes a 150 pound release from a single cylinder located in Building 124. Table 5.14-10 presents a listing of impacts to the immediate worker, co-located worker, and MOI for this revised chlorine release scenario.

The only other building that utilizes sulfur dioxide in a significant quantity is Building 881. However, the total building quantity (approximately 300 pounds) does not exceed the screening thresholds used in this analysis and therefore a release was not postulated.

The current inventory of nitric acid in the outside storage tank at the Building 371/374 Complex is expected to meet the current and future building needs without procuring additional quantities. As a result, the consequences of the postulated nitric acid release will continue to be reduced as the inventory is utilized.

The site propane inventory is also expected to decrease as the demand is reduced. However, the scenario that is postulated here will remain as a realistic scenario as long as any of the eight tanks at either propane tank farm are used for storage.

Table 5.14-10. Estimated Impacts for Chlorine Release - *Closure Case*

		150 lb. Cl (worst case meteorology)	**150 lb. Cl (average meteorology)**
Maximum Distance To:	ERPG-1	2.9 km	1.3 km
	ERPG-2	1.6 km	756 m
	ERPG-3	485 m	275 m
Maximum Consequences			
Immediate Worker (30 m)	Parts per million (ppm)	1,760	1,040
	Level of Concern	> ERPG-3	> ERPG-3
	Potential Health Effects	**Life Threatening**	**Life Threatening**
Co-located Worker (100 m)	Parts per million (ppm)	219	131
	Level of Concern	> ERPG-3	> ERPG-3
	Hazard Quotient	219	131
	Potential Health Effects	**Life Threatening**	**Life Threatening**
Maximally Exposed Off-site Individuals (1,068 m)	Parts per million (ppm)	6.2	1.6
	Level of Concern	> ERPG-2	> ERPG-2
	Hazard Quotient	6.2	1.6
	Potential Health Effects	**Irreversible**	**Reversible**

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5.15 Cumulative Impacts

Past and present actions are included in the descriptions in Chapter 4, "Affected Environment." There is no attempt to conduct a retroactive consequence analysis, aside from stating current conditions. Future non-DOE actions are those probable projects and continuing trends, such as population shifts, land development around the Site, etc. external to DOE actions within the affected communities, within the CID timeframe. Because of the high level of uncertainty, the discussion of these future non-DOE actions must be qualitative. It should be noted that the actions that are relevant may differ by resource being analyzed cumulatively. For example, actions that affect biological resources are different from actions that affect socioeconomics.

Local Projects Contributing to Cumulative Impacts

This section describes planned projects for development of the land surrounding the Site. Population and employment factors, housing projections, and community development plans have been used as the basis for estimating future growth in the region. Figure 5.15-1, "Current and Planned Land Use Activities Surrounding the Site," provides an overview of planned development activities within a 5-mile radius of the Site during the CID timeframe. Table 5.15-1 describes some of the larger non-DOE projects near the Site which, considered cumulatively with DOE's proposed actions, could have an impact on the surrounding environment.

Activities that typically induce further growth include:

- Extension of urban services into a previously unserved area;
- Extension of transportation facilities or utilities (water, power, telephone, etc.) into an area that may allow it to be subsequently developed;
- Removal of physical or policy obstacles to growth; or
- Generation of substantial new employment opportunities that are not consistent with planned community development as directed by local plans and policies.

Cleanup of the Site to open space land use standards might be considered a growth-inducing impact, since options for use of surrounding lands would increase, and future development would become more likely.

As the population of the Front Range expands, historic low-impact uses of the land surrounding the Site (i.e., ranching and open space) are giving way to higher-impact commercial and residential development. Cumulative impacts of such development would include increased traffic congestion, and perhaps related reductions in air quality, and decreased wildlife habitat (in particular contiguous habitat) for wildlife and possible sensitive plant species. Although it is likely that some open space land would be preserved, overall impacts to the environment would be adverse.

Several projects and activities surrounding the Site summarized in Table 5.15-1 are discussed in more detail below. Proposed development surrounding the Site is addressed in clockwise order, beginning north of the Site.

Table 5.15-1. Potential Development Surrounding the Site from 1996 to 2006

Project	Description	Potential Impact
Rock Creek Residential Development	Development of 4,000 homes with light commercial facilities to support area population growth.	Change from semi-rural lands to developed land. Erosion of visual aesthetics. Population density increase. Increased traffic and habitat disturbance
Interlocken Office Park	An integrated business park, golf resort, public recreational park, and commercial development.	Change from rural/pastoral environment to business/light commercial development with open space. Erosion of visual aesthetics. Increased traffic and habitat disturbance
Jefferson County Airport	A regional airport serving the north Denver Metropolitan Area's private and light commercial air traffic.	No change to flight paths or airport size anticipated during CID timeframe.
City of Westminster Expansion	Continued residential development on the western boundary of the City of Westminster. Construction of an athletic stadium near the southeast corner of the Site.	Increased traffic, land use, and infrastructure impacts from increased population in the area. Visual impacts from blocking of mountain views and glare from nighttime lighting. Impacts to raptors using the area as hunting and nesting grounds. Increased traffic from athletic event attendance.
City of Arvada Expansion	Continued residential development on the western and northwestern boundaries of the City of Arvada.	Increased traffic, land use, and infrastructure impacts from increased population in the area.
Jefferson County Purchase of Land for Open Space	Purchase of over 1,000 acres of ranch land to be designated for open space.	Continued availability of natural lands to the public; preservation of scenic qualities and habitat.
Western Aggregate Mining	Expansion of mining on the northwest and western boundaries of the Site.	Impacts to the rural nature of the land to be mined. Increased truck traffic, dust, and habitat disturbance. Erosion of visual aesthetics. Hydrologic impacts.
Other Commercial Development	Mountain View Tech Center; Mountain Plains Industrial Center; 96th Street Interchange.	Continued change from semi-rural lands to commercial development; continued erosion of visual aesthetics. Increased traffic and habitat disturbance
National Renewable Energy Laboratory (Wind Energy Site)	Potential development of additional wind machines or buildings.	Negligible impacts from continued operations; potential impacts to raptor habitat from additional development.

POTENTIAL DEVELOPMENT NORTH OF THE SITE. The Rock Creek residential development in the Town of Superior is expected to contain 4,000 homes at completion. The site was annexed in 1987 with a projected build out period of 20 to 25 years. Rock Creek is indicated on Figure 5.15-1 (Activity 1). Land to the west of McCaslin Boulevard and to the west of the Rock Creek residential development is currently zoned for either residential or light commercial. Plans for this area have not been finalized by the Town of Superior.

Within a 5-mile radius of the Site, pockets of existing and planned residential areas are interspersed with ranch land, open space, and light commercial development. Residential growth over the next ten years is anticipated to be most extensive in the Rock Creek development area and to the east along the western edge of Westminster and Arvada.

POTENTIAL DEVELOPMENT NORTHEAST OF THE SITE. To the northeast, the Interlocken business park and resort continues to expand according to a three-phased plan approved by the City of Broomfield. Interlocken is expected ultimately to include several office buildings, public parks, a 300-room hotel, a 27-hole golf course, an athletic club, and a series of running and bicycling trails (see Figure 5.15-1 for the general location, Activity 2). Phase I has been completed. It is anticipated that Phase II will be completed in early 1997. Phase III is expected to be completed shortly after the turn of the century.

Interlocken's growth is also adjacent to the development of the Highway 36 (the Boulder Turnpike) interchange at 96th Street. Commercial development at this interchange may include an upscale regional retail mall and a group of smaller service businesses, such as printers, dry cleaners, and restaurants.

To the east and slightly north of the Site, the Jefferson County Airport serves the northwest Denver Metropolitan Area, with capabilities for light aircraft and some small commercial jet aircraft (see Figure 5.15-1, Activity 3). In addition, the federal government (the National Center for Atmospheric Research and the U.S. Forest Service) makes a few flights with larger aircraft on a limited basis each year. The flight paths for all air traffic at the airport currently occur over the Rock Creek residential development, according to existing approved aviation easements.

POTENTIAL DEVELOPMENT SOUTHEAST OF THE SITE. Expected commercial development projects include the Mountain View Tech Center at the intersection of Indiana Street and 96th Avenue, south of the southeast corner of the Site. Information regarding the Mountain View Tech Center is provided in the 1990 *Land Use Plan* written for Jefferson County. Negotiations are also underway with the City of Westminster to build a proposed athletic stadium at or near the junction of Indiana Street and 96th Avenue.

POTENTIAL DEVELOPMENT SOUTH OF THE SITE. The Jefferson County Landfill occupies an expanse of property south of Highway 72 and east of Highway 93; this landfill could expand to the north and east in the future (shown on Figure 5.15-1 as Activity 4).

POTENTIAL DEVELOPMENT SOUTHWEST OF THE SITE. The Jefferson County Open Space Department is in the process of purchasing 708 acres of the Quarter Circle Ranch west and southwest of the Site to preserve visual aesthetics. The acreage is located west of Highway 93 and north of Highway 72 (shown on Figure 5.15-1 as Activity 5). The easternmost bank of Coal Creek is the eastern boundary; the road to Plainview cuts the property in half. Jefferson County's Open Space Department is currently negotiating to purchase 200-acre, 75-acre, and 35-acre properties near the junction of Highway 72 and Highway 93 to preserve as open space.

POTENTIAL DEVELOPMENT WEST OF THE SITE. Western Aggregates, Inc. currently performs mining operations adjacent to the northwest corner of the Site and within the Site Buffer Zone (see Activity 6 on Figure 5.15-1). Operations are limited to mining; materials processing is accomplished off-site. Western Aggregates has petitioned and gained approved from Jefferson County to expand mining operations in two areas—a 425-acre area which includes the National Renewable Energy Laboratory site and a portion of the Buffer Zone, and a 650-acre area near Rocky Flats Lake (which is not part of the Site). Western Aggregates anticipates that a 30-year resource of materials is available in the 1,075-acre expansion. In addition, Western Aggregates may initiate mining within the next five years along a 110-acre strip southwest of the Site, and expand its current mining operations on the west side of Highway 93 to the west and north of the Site by approximately 100 acres. Further expansion will depend upon the Jefferson County Commission's approval.

McKay Construction proposed commercial development along Highway 93, north of Highway 72 and between the highway and the north-south Southern Pacific railroad spur to the east. This development is referred to as the Mountain Plains Industrial Center.

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There are two operational Southern Pacific railroad spurs on and west of the Site. Western Aggregates is currently using the westernmost spur (which is a north-south spur just beyond the western boundary of the Site). Approximately 100 rail cars per month are moved each way along this spur to transport Western Aggregates' mining materials to their processing plant. The number of rail cars could increase with expanded mining, although it is believed that much of the additional materials would be handled by truck rather than rail. The other rail line spur is intended for use by the Site; this spur was used in 1996 for over 40 shipments (e.g., DD&D of the fuel oil tanks). The purpose of the spur is to transport materials from the site to the main railroad line south of the Site and is expected to be utilized for DD&D activities.

POTENTIAL DEVELOPMENT NORTHWEST OF THE SITE. Boulder County and the City of Boulder own significant parcels of open space land to the north and northwest of the Site. Although some residential areas occur along the open space boundaries, the primary use is open space to the public.

The Wind Energy Test Center is located along the northwest boundary of the site. The Center was turned over to the National Renewable Energy Laboratory on July 1, 1993. Large scale research of alternative energy sources is conducted at the Center. Future plans include expanded wind generation.

To the west of Interlocken, the Town of Superior plans a light commercial/retail complex at the McCaslin Boulevard interchange with Highway 36. These facilities are anticipated to provide infrastructure to support the expanding Rock Creek residential development to the west of Interlocken. The City of Louisville, to the north of Highway 36, has begun commercial development on the northern side of the same interchange, including a series of restaurants and a major movie theater complex.

Geology

Given that the impacts to geological resources are negligible or low under both CID cases, no cumulative impacts are anticipated.

Soils

The cumulative impact to soil resources at the Site would not be affected by development activities off-site. For the broader area, however, cumulative impacts from residential, commercial, or industrial development activities could be offset, to a small degree, by the long-term moderate increase of soil productivity under the *closure* case—particularly where these developments displace land previously used for open space or ranching activities. Under the *baseline* case, soil productivity would continue at present reduced levels on the Site, which would add minimally to the loss of long-term soil productivity for the broader area. No long-term cumulative impacts as a result of soil erosion are anticipated.

Water

While surface activities associated with remediation and construction under either case could result in local, short-term impacts to alluvial ground water and surface water quality, in the long-term, under each of the cases, there will be impacts to hydrological resources. Closure of the Site Waste Water Treatment Plant will stop discharge of treated effluent to the Walnut Creek drainage.

The cumulative impacts associated with either of the cases and any potential developments in the region of the Site would include increased surface runoff associated with any residential or commercial plans and decreased ground water recharge. Use of caps would increase surface water runoff and decrease ground water recharge. These impacts cannot be quantified at this time. Whether mitigation must occur is subject to negotiations between the Site and the lead regulatory agency.

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Reduction of water usage by the Site during closure may result in decreased flows and reduction in water held by the detention ponds. This reduction in flows may reduce the viability of some wetlands habitat, riparian habitat, and open water habitat. However, under the *closure* case the ponds are to be converted to a flow through system and eventually to wetlands increasing the long term wetland availability.

Air

No additional radiological air quality impacts are anticipated from any of the potential regional development projects planned during the CID timeframe. However, it is worthwhile to examine the potential cumulative impacts from the perspectives discussed below.

<u>Radiological Air Quality.</u> Airborne radiological doses to workers and members of the public related to Site activities are only a fraction of the total doses received. Residents and workers in the Denver Metropolitan Area are also exposed to a variety of background radiation sources such as cosmic radiation, geological sources, and radon. However, there are no additional identified point sources of airborne radiological exposure in the vicinity of the Site. Total doses to workers and members of the public are discussed below in "Human Health and Safety."

<u>Nonradiological Air Quality.</u> The dispersion modeling analysis performed for the nonradiological air quality impact assessment included impacts from other nearby sources along with background concentrations for specific pollutants. This method of analysis is appropriate when ambient air quality standards are used as a measure of adverse impact from the Site. Thus, the total predicted off-site concentrations presented in Section 5.5.2, "Nonradiological Air Quality," represent a cumulative impact at the point of maximum concentration for each pollutant. All estimated levels of criteria and toxic air pollutants are below applicable federal and state air quality standards and recommended values.

Cumulative Impacts from Traffic and Transportation

Cumulative traffic and transportation impacts are important primarily with respect to traffic. Commuter and truck volume from the Site would combine with other traffic in the vicinity, potentially causing congestion problems. In the Closure Case, personal vehicle traffic decreases over the Base Case by approximately 50% (due to a decreasing workload), and commercial truck traffic would increase by up to a factor of ten. These incremental volumes could contribute to road congestion during peak traffic hours. This effect could be lessened by staggering working hours and truck arrival and departure times. A quantitative traffic analysis was not within the scope of the CID; therefore, estimates of the quantitative importance of this additional traffic under current conditions and with future regional development are not available.

Some cumulative effects could also be seen with respect to routine transport of nuclear waste and materials. A variety of sites and projects across the nation will be shipping radioactive materials to different receiver sites. The primary cumulative impact is from the increase in traffic accidents resulting in fatalities, and potential latent cancer fatalities from diesel emissions, fugitive dusts, and brake/tire wear. The cumulative impact from cargo releases, both from radiological and hazardous chemicals, is negligible, including both incident-free transportation and potential accidents. A slight cumulative effect exists where routes intersect in terms of radiological impacts to workers and members of the public along the routes. In general, route overlap or intersection will be most important near the receiver site and would be evaluated by the receiver site. For this reason, the cumulative radiological effects with respect to Site waste were not analyzed in the CID.

Human Health and Safety

No additional radiological or nonradiological human health impacts are anticipated from any of the potential development projects planned during the CID timeframe and therefore there would be no additional cumulative impacts. Impacts from the *baseline* and the *closure* cases are discussed in detail in section 5.8.

Ecological Resources

VEGETATION. Under the *closure* case a larger area of upland habitat (374 acres), including less than 100 acres of native grassland would be disturbed. Best management practices would be expected to counteract long-term loss of native grassland habitat. Disturbed areas, developed areas, and reclaimed grassland account for 71% of the upland habitat that would be disturbed under this case. The long-term beneficial impacts of reclaiming these areas with native species would cumulatively offset a portion of the short-term adverse impacts associated with disturbing native grassland communities, as well as not exacerbate potential losses of native grasslands due to development activities in the region.

WETLANDS. The *baseline* and *closure* cases would result in substantial short-term impacts upon wetland and riparian habitat. However, assuming successful implementation of best management practices, the long-term impacts to wetland and riparian resources at the Site would be low. The cumulative impact to wetland and riparian habitats in the region would depend more upon the level of impact for each of the development projects. However, it is beyond the scope of this CID to identify wetlands in the region, or evaluate the impacts of the various projects upon them. The contribution to a cumulative impact from any of the cases would be low. There would be no cumulative impacts from physical disturbance under the *baseline* case, since no additional impact to wetland and riparian habitats is anticipated. Under the *closure* case ponds are to be converted to a flow through system and evenly converted to wetlands. This would offset some wetlands losses due to other development projects in the area.

SENSITIVE HABITATS. The *baseline* case would result in no additional impacts to sensitive habitats, and therefore would result in no cumulative impacts.

Short-term impacts to sensitive habitats occur under the *closure* case. However, implementation of best management practices and successful reclamation measures would result in low long-term impacts. The cumulative impact to sensitive habitats in the region would depend more upon the level of impact for each of the off-site development projects. However, it is beyond the scope of this CID to identify sensitive habitats in the region, or evaluate the impacts of the various off-site projects upon them. The contribution to a cumulative impact from any of the cases would be low during the long-term.

WILDLIFE. The *baseline* case would result in no additional impacts to wildlife, and therefore would result in no contribution to cumulative impacts from Site activities. Site operations under the Closure case would result in disturbance of key receptor species habitats, which are considered substantial short-term impacts. However, the *closure* case also includes plans to reclaim affected areas and revegetate them with native plant communities within the CID timeframe. Implementation of reclamation measures would result in low long-term impacts. The cumulative impact to wildlife in the region would depend on the level of impact of off-site development projects. However, it is beyond the scope of this CID to identify wildlife in the region, or evaluate the impacts of the various off-site projects upon them. The contribution to a cumulative impact from any of the action alternatives would be low during the long term.

AQUATIC FAUNA. The *baseline* case would result in no additional impacts to aquatic fauna, and therefore would result in no cumulative impacts. Under the *closure* case, aquatic fauna would experience impact from permanent loss of aquatic habitat on the Site, which, when combined with potential impacts if developments in the area also affect aquatic fauna, could also represent a cumulative impact.

SPECIES OF SPECIAL CONCERN. The *baseline* case would result in no additional impacts to species of special concern, and therefore would result in no cumulative impacts. Species of special concern would be affected in the short-term under the *closure* case, through varying degrees of habitat. It should be noted, however, that the loss of suitable habitat on-site is small, comparable habitat would be available elsewhere, and reclamation measures would reduce the on-site impacts

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to low short-term ones. However, if the planned development activities affect comparable habitats, there could be a cumulative impact to these species of special concern.

BIODIVERSITY. Cumulative impacts on regional biodiversity could occur as a result of the planned development activities in the area, depending on the degree of impacts from those projects. Because the *baseline* case does not include activities in the Buffer Zone, it would have no cumulative impact upon regional biodiversity. Under the *closure* case reduction of open-water habitat that would result in lower diversity of aquatic species on Site. However, in a regional context and given the low habitat quality and relatively small area affected, it is considered a negligible impact. If reclamation restores—and therefore eventually increases—wetland diversity, the long-term impact would be to return to *baseline* biodiversity levels. Thus, no long-term cumulative impacts would be expected under this biodiversity case.

Cultural Resources

Because no additional adverse impacts are anticipated to cultural resources under both cases, no cumulative impacts would occur.

Visual Resources

The visual quality impacts at the Site are considered low under the *baseline* and *closure* cases. As development continues in the northwest Denver Metropolitan Area, the region surrounding the Site would experience the cumulative effects of encroaching suburban residential development, particularly to the north; continued commercial and industrial development surrounding the Site; and increased traffic associated with this growth near the Site. This development and increased traffic would be visible from vantage points, and overall could result in a cumulative impact to visual quality in the area. However, much of the land southwest of the Site is used as open space, and northwest of the Site potential development includes purchases by the Jefferson County Open Space Department of large sites to preserve visual aesthetics. This would tend to offset some of the negative cumulative visual impacts.

Noise

Activities at the Site under the Closure Case combined with development around the Site would result in minor cumulative noise impacts to surrounding land uses. This is primarily due to noise impacts along state routes and local roadways would occur as a result of increased trips to the Site. Under the Closure Case, remediation would result in a higher volume of traffic than currently occurs under the Baseline Case. As noted in the Section 4.11, "Noise," the background noise level survey included noise levels from the surrounding land uses adjoining the Site. In this respect, the baseline noise survey included cumulative noise levels from many sources. The estimated noise impacts resulting from the CID Baseline and Closure Cases would be in addition to the existing noise baseline. If the potential development projects result in noise-sensitive residential development adjacent to the Site, the additional traffic generated by the cleanup activities in the Closure Case, would exacerbate noise impacts to those land uses. It is not possible to quantify the degree of those impacts, since specific data on the potential projects are not available.

Socioeconomics

The Site exists near several highly populated areas in the Denver Metropolitan Area that are projected to have growing economies, including during the CID timeframe.

Based on employment projections compiled by the Denver Regional Council of Governments for the six-county Denver Metropolitan Area, employment is projected to increase at a rate of 1.4 percent per year, for a total increase of 17.5 percent, between 1994 and 2006, as shown in Tables 5.12-3 through 5.12-5 and discussed in Section 5.12. It should be noted that the projections, developed by the Denver Regional Council of Governments, assume the reduction of 4,000 jobs associated with the *closure* case. In addition, two separate recent studies (conducted by the Rocky Flats Local Impacts Initiative and EG&G Rocky Flats, Inc.) on the re-employability of workers who would lose Site jobs, found that much of the Site's work force is experienced and well-educated, with skills that are attractive to other potential employers, and should be able to re-enter the labor market which is projected to grow in the Denver Metropolitan Area.

The adverse socioeconomic impacts from direct work force changes at the Site, and their related direct and indirect impacts on the area's expenditures and non-residential space availability, under both cases would not be expected to cumulatively, substantially affect the surrounding region, since the negative impacts resulting from the Site's direct and indirect work force reductions would be counterbalanced by the additional growth projected in the area. The growing local economy would facilitate job transition for those who would lose jobs as a result of reductions in Site activity, and lessen the impact on businesses that sell goods and services to the Site or its vendors.

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Appendix A:
Traffic and Transportation

A-1 Introduction

This appendix of the Cumulative Impacts Document (CID) describes the analysis of impacts from transportation activities both on-site and off-site for the *Baseline* and *Closure* Cases. The analysis considers impacts from routine transportation, both vehicle-related and cargo-related (e.g., hazardous materials), as well as potential accident conditions. The analysis considered incident-free transportation of radioactive materials, as well as potential accidents. The analysis also considered incident-free transportation of hazardous chemicals; however, potential accidents involving hazardous chemicals was not considered as this was assumed to not be significant compared to the impacts from transportation of radioactive materials, and other impacts from traffic fatalities due to incident-free transportation and accidents.

Transportation is an integral component of the *Baseline* Case and *Closure* Case being considered for each type of radioactive material. The types of radioactive materials considered are special nuclear materials (SNM), low-level waste (LLW), transuranic waste (TRU), low-level mixed waste (LLMW), and transuranic mixed wastes (TRU-mixed). The magnitude of transportation-related activities varies with *Baseline* and *Closure* Cases, ranging from minimal transportation to substantial transportation activities. The human health risks associated with transporting various radioactive materials were assessed to ensure a complete appraisal of the impacts of the *Baseline* and *Closure* Cases.

This appendix provides additional detail regarding the approach used to assess human health risks that may result from transporting Site materials. The assessment's scope, computer models used, important assumptions for each material type, and methods for determining potential routes for transportation are discussed. The risk assessment results are summarized and compared for the *Baseline* and *Closure* Cases. In addition, to aid in understanding and interpreting the results, specific areas of uncertainty are described, emphasizing how the uncertainties may affect the comparisons.

This appendix also describes the analysis used to assess the impacts on traffic in the immediate vicinity of the Site for *Baseline* and *Closure* Cases. Impacts assessed include the number of personal vehicles added to the local traffic, primarily by commuters to and from the Site, and commercial trucks used to transport materials to and from the Site. Methods are described for estimating the number of vehicles averaged over an annual period and over a 10-year analysis period, and a conservative estimate of the average traffic during the single year with the highest traffic impacts. For impacts beyond the 10-year analytical period, the estimated annual rate may be appropriate for specific activities that are not completed.

A-2 Transportation Activities Description

The following sections describe Site activities that will have impacts on, and be included in, the transportation risk assessment. On-site and off-site transportation of SNM, radioactive and nonradioactive waste, construction materials, and remediation materials has been considered. Where possible, waste receivers have been identified, and reasonable logic has been used to determine what types of activities will have a substantial impact on transportation risk. Several types of activities have been included, such as restoration of contaminated areas; waste treatment; storage and disposal; possible economic development; and deactivation, decontamination, and decommissioning activities.

The transportation risk assessment also included general activities not associated with specific tasks. These include commuter traffic, the use of on-site government vehicles in support of routine activities, and the delivery of materials (including hazardous materials) used for routine Site operations to and from the Site.

A-2.1 *Baseline* Case Transportation Activities

On-site and off-site transportation activities that occurred in 1996 are representative of *Baseline* Case conditions. On-site transportation included those routine, recurring activities necessary to support the Site operations and maintenance, as well as continuation of SNM consolidation into Building 371 (e.g., removal of SNM from Building 779 and other buildings). Off-site shipments consisted mostly of LLW and LLMW, a few pits to LLNL and LANL, and HEUN to Oak Ridge.

Some transportation activities occurred in 1996 to support environmental restoration activities involving monitoring, characterization, and remediation activities (e.g., soil remediation of trenches T2, T3, and T4, and removal of pond sludge to tanks). Deactivation involved off-site shipping of HEUN from Building 886 and SNM removal from Building 779. These activities did not have a significant impact on transportation volumes.

Most on-site waste handling operations do not have a substantial impact in relationship to off-site treatment, storage, and disposal operations. Solid and liquid plutonium residues[1] are stored on-site, as are TRU and TRU-mixed wastes. Sanitary waste is disposed of at the on-site landfill. LLW is disposed of at the Nevada Test Site, and LLW generated by the Sewage Treatment Plant is shipped to the Nevada Test Site. LLMW and hazardous waste will be disposed of at a commercial facility. Radioactive asbestos will be shipped to Hanford, and a local waste broker receives shipments of nonradioactive asbestos. Waste derived from environmental restoration activities will be shipped to off-site disposal facilities. Some SNM was shipped off-site, such as nuclear weapons components ("pits") shipped to other DOE sites.

A-2.2 *Closure* Case Transportation Activities

Closure Case environmental restoration includes excavation of areas exceeding appropriate contamination levels. All excavation material would be shipped off-site. Clean fill material and top soil would be brought on-site. Waste derived from deactivation, decontamination, and decommissioning activities that does not meet free-release criteria would be recycled or prepared for off-site shipment. Waste from these activities that meets free-release criteria and construction rubble from the demolition of buildings would be disposed of in the on-site landfill. *Closure* Case includes some economic development activities that would bring shipments of slightly contaminated material on-site. Security, maintenance, and surveillance activities and personnel are reduced dramatically during the analytical period as the Protected Area is scaled down and through the deactivation, decontamination, and decommissioning of buildings. This has the effect of reducing on-site transportation related to these activities as well as a substantial reduction in commuting travel.

Solid and liquid plutonium residues, TRU waste, and TRU-mixed waste would be treated and shipped to the Waste Isolation Pilot Plant. Some on-site transportation considerations would remain due to the construction of treatment facilities. LLW and LLMW would be temporarily stored on-site awaiting treatment and off-site transportation. LLW would be shipped to the Nevada Test Site. LLMW and LLW generated by the Sewage Treatment Plant would be shipped to the Nevada Test Site. Sanitary waste would be shipped off-site to a facility within a 50-mile radius of the Site. Hazardous waste would be shipped to a commercial facility, radioactive asbestos would be shipped to Hanford, and nonradioactive asbestos would be shipped to a local waste broker. Waste derived from environmental restoration activities would be transported off-site. All SNM would be shipped off-site. Uranium would be shipped to Oak Ridge National Laboratory.

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[1]The term "residues" is used in this appendix to refer to those materials that were not certified as TRU waste that could be shipped offsite or that were previously considered for economical recovery of the plutonium.

Plutonium metals and oxides would be shipped to Savannah River Site. Pits would be shipped to other DOE sites (selected pits for national laboratories, and the balance returned to Pantex).

A-3 Scope of Assessment

The scope of the transportation risk assessment, including the transportation-related activities described for the *Baseline* and *Closure* Cases, potential vehicle- and cargo-related impacts, receptors, and transportation destinations considered, are described in this appendix.

A-3.1 Existing On-Site or Off-Site Transportation Assessments

The *Site-Wide Evaluation of Transportation Risks for the Rocky Flats Plant* (EG&G 1992e) provides descriptions of Site transportation activities and their associated impacts and serves as the primary resource for relevant data and analyses for this risk assessment. The *Addendum to the Site-Wide Evaluation of Transportation Risks for the Rocky Flats Environmental Technology Site* (DOE 1995z) contains corrections and updates to be used in conjunction with this document. References to the *Site-Wide Evaluation of Transportation Risks for the Rocky Flats Plant* in this appendix include the corrections recommended in the addendum unless specified otherwise.

These documents provide sufficient information and analysis of on-site and off-site transportation activities and the associated potential impacts to human health and the environment required to support the requirements of 1) NEPA and its implementing regulations promulgated by the Council on Environmental Quality (40 *Code of Federal Regulations* 1500-1508), 2) DOE *Guidelines for Compliance with NEPA* (52 *Federal Register* 47662), DOE Order O 451.1, *National Environmental Policy Act Compliance Program* (DOE 1995kk).

Current NEPA analyses concerning Site transportation activities were identified and reviewed. For those activities that have been previously analyzed, the human health impacts were incorporated into this Cumulative Impacts Document (CID) by reference. For those activities which do not have specific NEPA analysis, assessment was conducted in the CID.

Table A-1 shows the existing NEPA documentation as it applies to the transport of materials to various destinations and the transportation parameters on which the analyses were based.

Table A-1. NEPA Transportation Documentation

Material	Destination	Existing NEPA Documentation
Low-Level Waste	Nevada Test Site Hanford On-site	*Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DOE 1996a) None identified None identified
Low-Level Mixed Waste	Nevada Test Site Oak Ridge or INEL for treatment Envirocare On-site	*Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DOE 1996a) *Waste Management Programmatic Environmental Impact Statement for Managing Treatment, Storage, and Disposal of Radioactive and Hazardous Waste* (DOE 1995m) None identified None identified
Transuranic Waste	Waste Isolation Pilot Plant On-site	*Final Supplement Environmental Impact Statement: Waste Isolation Pilot Plant* (DOE 1990a) and *Comparative Study of Waste Isolation Pilot Plant Transportation Alternatives* (DOE 1994u) None identified
Transuranic Mixed Waste	Waste Isolation Pilot Plant On-site	*Final Supplement Environmental Impact Statement: Waste Isolation Pilot Plant* (DOE 1990a) and *Comparative Study of Waste Isolation Pilot Plant Transportation Alternatives* (DOE 1994u) None identified
Residues	Waste Isolation Pilot Plant On-site	*Final Supplement Environmental Impact Statement: Waste Isolation Pilot Plant* (DOE 1990a) and *Comparative Study of Waste Isolation Pilot Plant Transportation Alternatives* (DOE 1994u) *Residue Drum Storage Facility Environmental Assessment* (EG&G 1992g)
RCRA Regulated	Commercial On-site	None identified None identified
TSCA Regulated Asbestos PCBs	Commercial	None identified
TSCA Regulated with Radioactive Contamination	Hanford	None identified
Sanitary Waste	On-site Off-site	*Environmental Assessment, New Sanitary Landfill at Rocky Flats Plant* (DOE 1994b) None identified
Hazardous	Commercial	None identified
Cap Material	On-site	None identified
Outgoing Plutonium Pits Scrub Alloy PuEU Composites	 Pantex, LANL, LLNL Savannah River Site LANL or LLNL	 *Storage and Disposition of Weapons-Usable Fissile Materials Draft Programmatic Environmental Impact Statement* (DOE 1996b)
Outgoing Enriched Uranium Metal Low Enriched Uranium	 Oak Ridge Y-12 Oak Ridge Y-12 or Nuclear Fuel Services	 *Environmental Assessment for the Proposed Interim Storage of Enriched Uranium Above the Maximum Historical Storage Level at the Y-12 Plant, Oak Ridge, Tennessee* (DOE 1994t)
Highly Enriched Uranyl Nitrate Solutions	Oak Ridge Y-12 or Nuclear Fuel Services	*Categorical Exclusion for Removal of Highly Enriched Uranyl Nitrate (HEUN) from Building 886* (DOE 1995aa)

The NEPA documents identified above provide the basis for off-site shipments to the Waste Isolation Pilot Plant. Adjustments were necessary only for waste volumes to be shipped under the *Baseline* and *Closure* Cases. Appropriate analyses for shipments of other radioactive or hazardous materials to other DOE facilities were also found in the *Site-Wide Evaluation of Transportation Risks for the Rocky Flats Plant* (EG&G 1992e).

Because the *Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DOE 1996a) and *Interim Draft Environmental Assessment of the Residue Drum Storage Facility* (EG&G 1992g) were both in draft stage when this CID assessment was started, the transportation impacts were analyzed for the CID. Some of the data developed for the draft documents were used in this analysis.

No specific NEPA documentation has been found to address shipments of waste to Hanford or Envirocare; therefore, analyses specific to these activities were performed for the CID. Table A-2 presents the level of coverage provided by existing NEPA documentation with respect to number of trips and quantity of material shipped.

Table A-2. Transportation Parameters for Each Material and Destination Covered by Existing Documentation

		Documentation Analytical Basis		*Baseline* Case Period		*Closure* Case	
Material	**Destination**	**Trips**	**Volume (yd^3)**	**Trips**	**Volume (yd^3)**	**Trips**	**Volume (yd^3)**
TRU	WIPP	7,608[1]	84,000[1]	0	0	0	0
TRU-mixed	WIPP	7,608[1]	84,000[1]	0	0	416	4,785
Residues	WIPP	7,608[1]	84,000[1]	0	0	0	0
SNM	Various DOE Sites	Not specified[2]	9.8 metric tons	few	classified	63[2]	9.8 metric tons
Sanitary Waste	On-site	26,000	300,000	8,050	118,424	11,959	183,320

[1]Total for all shipments from the Site.

[2]Number of shipments was not specified in the *Storage and Disposition of Weapons-Usable Fissile Materials Programmatic Environmental Impact Statement* (DOE 1996b), therefore, full shipments (35 packages) were assumed, which would require 63 shipments for all Site SNM. The actual number of shipments will be based on many factors, including the readiness of both sites and availability of shipping packages, and could result in more than the assumed 63 shipments. For the CID, risk was calculated on a weight basis and accounts for only routine radiological health effects.

A-4 Type of Transportation Impacts Analyzed

Transportation activities were examined from several aspects. Both on-site and off-site transportation activities were considered. For both of the categories, cargo-related and vehicle-related impacts were considered for both normal operations and accident conditions.

<u>ON-SITE TRANSPORTATION.</u> On-site transportation involves transporting waste or materials within the Site boundaries. Manual transfers of materials within a specific facility or between

connected facilities are not considered on-site transfers but are considered part of normal facility operations.

The relatively short distances traversed and small number of off-site transportation events do not permit determination of accurate statistical characterization necessary for many transportation models. For this reason, analytical methods used for on-site transportation analysis are different than those used for off-site transportation analysis.

The human health risks associated with on-site transportation are generally much smaller than those from off-site transportation, largely because of the limited distances for on-site shipment, limited population densities along the routes, and limited average travel speeds. Accordingly, the impacts of on-site transportation are not likely to contribute substantially to differences between the *Baseline* and *Closure* Cases.

OFF-SITE TRANSPORTATION. Off-site transportation refers to transporting a cargo between distinct DOE sites or commercial sites, including on-site parts of the routes that may be within the boundaries of the origin and destination sites.

Off-site transportation involves radioactive material, other hazardous material and nonhazardous material shipments moving through a constantly changing landscape and potentially stopping at any place along a route. To effectively describe this situation, models that use simplified assumptions and generalizations are used to estimate risk from off-site shipments. National average or typical values are chosen for variables such as road and track dimensions, vehicular speed, traffic density, weather conditions, and stop times; population densities are modeled as being uniformly distributed.

Although materials may be much the same, the transportation conditions are different from on-site and require different analytical methods. Off-site transportation routes involve the use of public roadways for which a large body of experience and data involving large numbers of vehicles and events are available. Analytical models exist that are appropriate and applicable to many parts of the off-site analysis.

A-4.1 Cargo-Related Impacts

RADIOLOGICAL IMPACTS. Cargo-related impacts on human health during the transportation of radioactive materials would be caused by exposure to ionizing radiation. Radiological risk (risks resulting from the radioactive nature of the waste) are assessed for routine (normal) transportation and for accidents. These radiological risks associated with routine transportation result from the potential exposure of people near a loaded shipment to low levels of external radiation. The radiological risk from transportation-related accidents lies in the potential release and dispersal of radioactive material into the environment during an accident and the subsequent exposure of people through multiple exposure pathways, such as direct exposure to contaminated soil, inhalation of radioactive particles, or ingestion of contaminated food.

The potential exposures to the public from transporting radioactive materials, either from routine operations or from postulated accidents, are usually at such a low dose that the primary adverse health effect is the potential induction of latent cancers (that is, cancers that occur several years after the exposure). Radiological impacts are expressed as health risks in terms of the number of estimated excess latent cancer fatalities in exposed populations for the *Baseline* and *Closure* Cases. Health risk conversion factors (expected latent health effects per dose absorbed) are excerpted from the International Commission on Radiation Protection - Publication 60 (ICRP 1991b).

HAZARDOUS CHEMICAL IMPACTS. Cargo-related impacts to human health during transportation of hazardous chemicals or hazardous wastes would be caused by exposure resulting from package failure and chemical release during an accident (a collision with another vehicle or road obstacle). Packagess used for shipping hazardous waste have been specified by the U.S. Department of

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Transportation (DOT) and have been assumed to preclude any substantial exposure of workers or the public during routine hazardous waste transport under routine conditions.

The risks from hazardous waste exposure during transportation accidents can be either acute (resulting in immediate injury or fatality) or latent (resulting in cancer that becomes evident after a latency period of several years). Population risks and risks to the maximally exposed individual were evaluated for transportation accidents. Acute effects were evaluated by comparing accident concentrations to reference concentrations and doses published by EPA (HEAST and IRIS). A latent health endpoint, increased cancer risk, was also used to assess the cargo-related population impacts from accidents involving carcinogen releases. Traditionally, risk assessment for chemical carcinogens characterizes risk to the maximally exposed individual rather than a 50-mile population (EPA 1989a). The maximally exposed individual assessment is included in the hazardous waste transportation risk analysis.

Inhalation is the primary exposure route of concern for accidental release of hazardous materials. Although direct exposure to hazardous materials by other pathways, such as ingestion or dermal absorption, is also possible, these routes are expected to result in much lower exposure than the inhalation pathway doses.

A-4.2 Vehicle-Related Impacts

In addition to the risks posed by cargo-related activities, risks are also assessed for vehicle-related impacts for off-site transportation. These risks do not depend on the of the cargo and would be incurred for similar shipments of any material. The vehicle-related risks are assessed for routine conditions and potential accidents. Vehicle-related risks during routine transportation are caused by potential exposure to increased vehicular exhaust emissions, fugitive dusts, and tire and brake wear. Vehicles are required to be maintained to minimize these emissions, and are periodically inspected by Site personnel. These routine risks are primarily associated with travel in urban environments.

The health endpoint assessed under routine transport conditions is the excess (additional) latent mortality caused by inhalation of vehicular exhaust emissions. A risk factor for latent mortality from pollutant inhalation, generated in *Nonradiological Impacts of Transporting Radioactive Materials* (Rao 1982), is 1×10^{-7}/km (1.6×10^{-7}/mi) of truck travel in an urban area. This risk factor is based on regression analyses of the effect of sulfur dioxide and particulate releases from diesel exhaust on mortality. Excess latent mortality is assumed to be equivalent to cancer fatalities. Vehicle-related risks from routine transportation are calculated for each case by multiplying the total distance traveled in urban areas by the appropriate risk factor. Similar risk factors are not available for rural and suburban areas and therefore cancer risk for the rural route is assumed to be insignificant compared to that from the urban route.

Vehicle-related impacts also include traffic fatalities. State-specific rates for transportation-related fatalities are used in the assessment.

Risks are summed over the entire route and over all shipments for *Baseline* and *Closure* Cases. This method has been used in several reports to calculate risks from routine transport of radioactive wastes. It provides a convenient method of comparing the risks of radioactive waste transport versus hazardous waste transport under routine conditions.

A-5 Transportation Regulatory Environment

All policies approved for the Site operations are summarized in the *Policy and Procedures Manual*, which forms the highest level (Level 1) element of Site document hierarchy. Current Site requirements regarding transportation activities are specified in the *Rocky Flats Transportation Safety Manuals* (Kaiser-Hill 1995d). Currently identified regulatory and agency requirements affecting the transportation requirements are summarized in Table A-3 (however, some of these DOE Orders are in the process of being replaced by the "O-series" of Orders).

Table A-3. Regulatory and DOE Transportation Requirements

DOE Orders	Requirements
O 151.1	Comprehensive Emergency Management System
O 232.1	Occurrence Reporting and Processing of Operations Information
O 225.1	Accident Investigation
O 440.1	Worker Protection Management for DOE Federal and Contractor Employees
O 460.1	Packaging and Transportation Safety
O 460.2	Departmental Materials Transportation and Packaging Management
O 470.1	Safeguards and Security Program
5400.5	Radiation Protection of the Public and the Environment
5480.4	Environmental Protection, Safety, and Health Protection Standards
5481.1B	Safety Analysis and Review System
5482.1B	Environment, Safety, and Health Appraisal Program
5484.1B	Environmental Protection, Safety, and Health Protection Information Reporting Requirements
5610.12	Packaging and Off-site Transportation of Nuclear Components, and Special Assemblies Associated with the Nuclear Explosives
5610.14	Transportation Safeguards System Program Operations
5632.1C	Protection and Control of Safeguards and Security Interests
5700.6C	Quality Assurance (for non-nuclear activities)
5820.2A	Radioactive Waste Management
Other DOE Requirements	
–	DOE Explosives Safety Manual
Federal Regulations	
10 CFR	Energy
10 CFR 835	Occupational Radiation Protection
10 CFR 830.110	Quality Assurance Requirements (for nuclear activities)
29 CFR 1910	Occupational Safety and Health
40 CFR	Protection of the Environment
42 CFR	Medical wastes
49 CFR	Transportation
State Regulations	
CRS § 40-10-101	Motor Carriers
CRS § 40-11-101	Contract Motor Vehicles
CRS § 40-13-101	Towing Carriers

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Site policy stipulates that the transportation of all materials to, from, or within the Site comply with federal, state, and internal regulations and requirements. The on-site transportation policy requires that all hazardous and radioactive materials be marked, labeled, handled, transported, and/or stored in approved packages, using methods and procedures to ensure compliance with applicable regulations. It is further Site policy that no government property be taken off the Site without appropriate authorization. Within the scope of the first two policy statements is the principle that transportation-related exposures and environmental impacts be maintained as low as reasonably achievable (ALARA) in accordance with DOE Order 5480.4.

Packages used for on-site transportation of hazardous materials at the Site that do not meet U.S. *Baseline* and *Closure* Cases specifications must provide "equivalent protection," e.g., must withstand a 4-foot drop without loss of contents and must also meet the requirements of 49 CFR 173.24 (a) and (b) and applicable Site procedures. Additionally, packages used for on-site transport of radioactive materials must also meet the requirements of 49 CFR 173.411, 49 CFR 173.421, 49 CFR 173.442, 49 CFR 173.441, and 49 CFR 173.443. Exceptions to these packaging requirements must be approved by an On-Site Transportation Safety Committee.

Vehicles transporting SNM, residues, and TRU wastes on the Site must be a closed-type vehicle to the greatest extent possible and must use the most direct route without undue delay during loading, transporting, and unloading and comply with other safety considerations required by Site procedures.

Outbound and inbound shipments made by commercial carriers or government-owned vehicles operated by other than government employees must be packaged, marked, labeled, and ready for transportation in accordance with 49 CFR Part 100-180, 350-399; Public Law 101-614 (training requirement); and the Transportation Safety Act of 1990. DOE shipments must meet all applicable regulations for the transport of all of its materials, including SNM.

A-6 Transportation Packaging and Other Requirements

Regulations that govern the transportation of radioactive materials are designed to protect the public from the potential loss or dispersal of radioactive materials and from routine doses of radiation during transit. The primary regulatory approach for ensuring safety is by specifying standards for the packaging of radioactive materials. Other preventive measures such as training of drivers, specialized material handling equipment, vehicle maintenance, etc., are also implemented to assure a high level of transportation safety.

Because packaging represents the primary barrier between the radioactive material and exposure of the public and environment to radiation, packaging requirements are an important consideration for transportation risk assessment. Regulatory packaging requirements and the representative packaging and shipment configurations assumed for each type of material considered in the CID are described in this section.

A-6.1 Site Packaging for Radioactive Materials

Although several federal and state organizations are involved in regulating the transportation of radioactive waste, the DOT and the U.S. Nuclear Regulatory Commission (NRC) have primary regulatory responsibility. In addition, DOE has formalized agreements with DOT and NRC to delineate responsibilities of each agency. All transportation-related activities must meet applicable regulations of these agencies specified in 49 CFR 100 - 180 and 10 CFR 71.

Packages for transporting radioactive materials must be designed, constructed, and maintained to ensure that they will contain and shield their contents during normal transportation. For more highly radioactive material, packages must contain and shield their contents in severe accidents. The type of packaging used is determined by the radioactive hazard associated with the packaged material. Three categories of packaging are DOT-approved for radioactive materials: Type A

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packages; Type B packages; and strong outer packages. The type of package used for a radioactive material shipment depends on general requirements set forth in 49 CFR 173 Subpart I and requirements for the specific shipping category.

Type A packaging must withstand the conditions of normal transportation without the loss or dispersal of the radioactive contents. "Normal" transportation refers to all transportation conditions including mishandling in transit but excluding those resulting from accidents or sabotage. These conditions are intended to accommodate mishandling and minor accidents. Type A packages are regulated by the DOE in consultation with the DOT. Approval of Type A packaging is achieved by demonstrating that the packaging can withstand specified testing conditions intended to simulate normal transportation. Type A packaging, typically a 208-liter (55-gallon) drum or standard waste box, is commonly used to transport wastes with low radioactivity levels. Type A packaging is routinely used in waste management for storage, transportation, and disposal. Type A packaging usually does not require special handling, packaging, or transportation equipment.

"Industrial packaging" designated as IP-1 or IP-2 may be used for the transportation of certain low level wastes under a Low Specific Activity (LSA) or Surface Contaminated Object (SCO) under an exception in 49 CFR. IP-1 packagings are similar to "strong outer packagings" except that there is a greater burden on the shipper to document the ability of the package to withstand conditions normally incident to transportation including ability to withstand vibration. IP-2 packages must meet IP-2 requirements and performance tests that are intermediate to Type A performance requirements.

"Strong outer packagings" may be used to transport certain low specific-activity materials (for example, mill tailings, uranium ore, and some LLW). Shipments of strong outer packages are exempted from certain packaging specifications and marking and labeling requirements but must still comply with many administrative controls. Strong outer packages must not leak under normal transport conditions. Examples of strong outer packages currently in use include steel drums, rectangular metal bins, and wooden boxes.

Type B packages are utilized for greater activities of radioactive materials and, in addition to meeting "normal" transportation conditions, are designed and tested to a series of hypothetical accident conditions (10 CFR 71.73). The DOT or DOE certifies Type B packages. Type B packages are often used for shipping multiple Type A packages when additional protection is required. In addition to meeting the standards for Type A packaging, Type B packaging must provide a high degree of assurance that the package integrity will be maintained, even during severe accidents, with essentially no loss of the radioactive contents or serious impairment of the shielding capability. The testing criteria were developed to simulate conditions of severe hypothetical accidents, including impacts, puncture, fire, and immersion in water.

External radiation allowed to escape from a package must be below specified limits that minimize exposure of the handling personnel and the public. Most DOE radioactive material shipments are handled only by the shipper and the receiver, an arrangement referred to as an "exclusive-use" shipment. For this type of off-site shipment (regardless of the material type or package), the dose rate for external radiation during normal transportation must be maintained below the following limits (49 CFR 173):

- Dose of 10 millirem per hour (mrem/hr) at any point 2 meters (6.6 feet) from the vertical planes projected by the outer lateral surfaces of the car or vehicle
- Dose of 2 mrem/hr in any normally occupied position in the car or vehicle (on-site limits are 5 mrem/hr in the cab).

Additional restrictions apply to radiation levels on the package surface; however, these restrictions do not affect the transportation-related radiological risk assessment.

For the purposes of risk assessment, specifying the actual package that will be used is unnecessary because all packages of a certain type are designed to meet the same performance criteria; for instance, a 55-gallon drum and a standard waste box, each designed to meet Type A

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packaging criteria, would be expected to behave similarly under routine transportation and accident conditions. The only difference is the quantity of radioactive materials which has been considered in the risk assessment.

Type A and Type B packaging test requirements are summarized in Table A-4. Additionally, Type A and Type B packaging must meet the requirements of 49 CFRs 173.24, 173.411, 173.412, 173.417, 173.463, 173.465, 173.466, 178.350, and 178.601; and DOE Order O 460.1, *Packaging and Transportation Safety* (DOE 1996q).

Table A-4. Normal Test Conditions for Type A and Type B Packages

Performance Parameter	Package Type	Test Condition[1]
Heat	A & B	Direct sunlight at an ambient temperature of 100°F in still air.
Cold	A & B	An ambient temperature of -40°F in still air and shade.
Pressure	A & B	Reduced external pressure of 3.5 pounds per square inch (psi) absolute and increased external pressure of 20.0 psi absolute.
Vibration	A & B	Vibration normally incident to transportation.
Water Spray	A & B	Sufficiently heavy to simulate rainfall of 2 inches per hour for 1 hour.
Free Drop	B	A free drop of 9 meters (30 feet) onto a flat, unyielding horizontal surface, striking in a position expected to do the most damage, through the distance specified (Note: defined by table from 1 to 4 feet, based on package weight).
Corner Drop	B	Onto each corner in succession (or each quarter of a cylindrical rim) from a height of 1 foot onto a flat unyielding surface (for all fissile Class II packagings and packagings weighing less than 110 pounds).
Compression	B	For 24 hours, a load of either five times the weight of the package, or 1.85 psi times the maximum horizontal cross-section of the package, whichever is greater, will be applied against the top and bottom of the packaging in the position in which the package would normally be transported (for packages less than 10,000 pounds only).
Penetration	B	Impact of the hemispherical end of a vertical steel cylinder 1_ inches in diameter and weighing 13 pounds, dropped from a height of 40 inches and striking perpendicular to the surface at a point on the package that is expected to be the most vulnerable to puncture.
Puncture	B	A free drop of 1 meter (40 inches), striking in a fashion for which maximum damage is expected, onto the top end of a vertical, cylindrical, mild steel bar mounted on an essentially unyielding horizontal surface. The bar is 15 centimeters (6 inches) in diameter, with the top horizontal and its edge rounded to a radius of not more than 6 millimeters (1/4 inch), and such a length as to cause maximum damage to the package, but not less than 20 centimeters (8 inches) long. The long axis of the bar is perpendicular to the unyielding horizontal surface.
Thermal Test	B	Exposure to a thermal test in which the heat input to the package is not less than that which would result from exposure of the whole package to a radiation environment of 800°C (1,475°F) for 30 minutes, with an emissivity coefficient of 0.9. The package may not be cooled artificially.
Immersion	B	Immersion in water to the extent that all portions of the package are under at least 15 meters (50 feet) of water for a period of not less than 8 hours.

[1]From 10 CFR 71.73.

Part 24(b) of 49 CFR 173 sets forth general requirements, which must be met for all packages used to ship radioactive or hazardous materials. In general, it states that all packages must be designed and constructed such that 1) under conditions normally incident to transportation, there will be no release of the hazardous material and 2) the effectiveness of the packaging will not be reduced.

Various radioactive and other hazardous materials are transported on and off the Site in support of the Site operations. This section presents descriptions of the packaging systems utilized for these transportation activities. Packages approved for movement of radioactive and other hazardous materials are identified in the *On-Site Transportation of Hazardous and Radioactive Materials Manual* (Kaiser-Hill 1995e).

Packaging systems for SNM entail multiple components and, depending on the specific model, may include multiple inner containers or a containment vessel, centering plates and polyethylene foam discs, celotex insulation, liners, an exterior container equipped with closure devices (e.g., bolting, lock-ring), and a filtered vent, as appropriate.

Truck shipments involving strategic quantities of SNM and certain classified nuclear weapons components are transported in government-owned Safe, Secure Trailers (SSTs). SSTs have been specially modified to enhance thermal and structural performance and, in conjunction with internal shipment packages, provide a multicomponent containment and packaging system. The SST is a mobile vault that is highly resistant to unauthorized entry and provides a high degree of cargo protection under accident conditions. SSTs are pulled by armored, penetration-resistant highway tractor. These transport vehicles are accompanied by armed couriers in escort vehicles equipped with communications and electronics systems, radiological monitoring equipment, and other equipment to enhance safety and security.

TRUPACT-II packaging is authorized for use to ship contact-handled transuranic waste to the Waste Isolation Pilot Plant. The TRUPACT-II has been certified by the NRC as a Type B package per 10 CFR 71. Major components of the packaging include stainless-steel containment vessels with removable lids surrounded by thermal insulation and a steel shell. Waste packages to be transported within the TRUPACT-II include Type A 55-gallon drums or standard waste boxes. The TRUPACT-II has a volume capacity of up to fourteen 55-gallon drums or two standard waste boxes.

Packages may be broadly categorized as Site-approved or DOT-approved (including DOE or NRC). Both package categories may be utilized to support transfer of radioactive and other hazardous materials on-site. On-site-approved packages must be capable of withstanding a 4-foot-drop test without loss of contents and must meet other 49 CFR 173 general requirements. Any exceptions must be approved by the On-Site Transportation Safety Committee and incorporate administrative controls that satisfy Site transportation policies (Kaiser-Hill 1995e). Only DOT-approved packages may be utilized for off-site shipments.

A-6.2 Material Transfer/Shipment Quantities

Package material limits for on-site transfers and off-site shipments are established by a number of criteria, including low level waste, TRU waste, and criticality safety criteria. A summary of containers that have been used for on-site or off-site transportation, is included in the technical support document for this transportation assessment (EG&G 1992e; EG&G 1995z). Some of these packages are no longer used for routine on-site transfers or off-site shipments, but they may still be used for storage of SNM or radioactive wastes which are not addressed by the Site transportation policies.

For analysis purposes, payloads were taken to be near the regulatory weight limit because the density of most materials is such that volume tends not to be limiting, and it is common practice to load trucks near the legal weight limit for economical reasons.

If the maximum payloads are used, the number of shipments is minimized, resulting in the least number of potential accidents, although the consequences are higher. Conversely, smaller payloads require more shipments, resulting in more potential accidents, each of lesser consequence. The risks, however, would be the same for the same total quantity of material to be transported.

A-6.3 Packaging for Mixed Waste

Future shipment of mixed wastes (LLMW and TRU-mixed) will be in the same type of currently-used packages for radioactive materials. Shipments of mixed wastes would meet additional requirements for characterization and labeling associated with the hazardous component. In addition, shipments of liquid waste would meet additional more stringent regulatory requirements specified for liquids; for example, packages would contain adequate absorbent material to absorb twice the volume of the transported liquid, or a leak-tight overpack would be used, and must withstand a 30-foot drop test (10 CFR 71).

A-7 On-Site Transportation Analyses

This section describes the analysis of human health impacts from transportation activities conducted at the Site under both incident-free and accident conditions.

A-7.1 Scope of Assessment

This section includes considerations of impacts due to the materials being transported on-site (cargo-related), especially radioactive materials, and impacts related only to the movement of vehicles without regard to the material being transported (vehicle-related).

A-7.1.1 Site Inventories and Projected Inventories

Table A-5 shows the volumes of material and number of on-site shipments for each alternative. Table A-6 shows the mileage estimated for vehicles used on-site but not associated with specific tasks.

Table A-5. On-Site Transportation Activities

Material	Source	*Baseline* Case		*Closure* Case			
		Trips/yr	Volume (yd^3)	Trips/yr	Volume (yd^3/yr)	10-yr Trips	10-yr Volume (yd^3)
Low-Level Waste	Operations	102	1,586	303	4,458	3,031	44,578
	Environmental Restoration	76	1,137	2,180	32,700	21,800	327,000
Low-Level Mixed Waste	Operations or Environmental Restoration	313	4,608	260	3,826	2,601	38,259
TRU	Operations	0	0	28	321	278	3,205
TRU-mixed	Operations	0	0	32	378	320	3,782
Residues	Operations	19	109	19	109	189	1,089
RCRA (hazardous)	Operations	0	0	19	271	185	2,713
Sanitary Waste	Operations	1,037	13,702	103	15,190	10,335	151,896
Cap Fill Material	N/A	0	0	18,000	270,000	180,000	2,700,000

Table A-6. On-Site Non-Specific Vehicle Mileage

Classification	*Baseline* Case		*Closure* Case		
	Average Employment	Miles/yr	Average Employment	Miles/yr	10-yr Miles
Government Vehicles	6,883	1.9×10^6	3,575	9.4×10^5	9.4×10^6

Volumes of material to be transported and numbers of shipments on-site are drawn from the following sources:

- The number of on-site waste shipments by alternative is taken from information collected for the waste processing estimates. Low level, low-level mixed, TRU, TRU-mixed, hazardous, TSCA, and sanitary wastes are included. Sources of waste include current inventories and material produced by waste treatment, waste storage and disposal activities, economic development activities, and DD&D activities.
- The volume of wastes generated by environmental restoration activities is taken from information gathered for the description of environmental restoration activities. The number of shipments is determined from the projected volumes divided by the average truck capacity of 14.7 cubic yards.

- Quantities of residues and number of residue shipments are taken from the work performed in support of the environmental assessment of the residue drum storage facility (EG&G 1992g).

A-7.1.2 On-Site Transport Routes

Vehicles transporting SNM, residues, and TRU wastes on the Site must be a closed-type vehicle to the greatest extent possible and must use the most direct route without undue delay during loading, transporting, and unloading and comply with other safety considerations required by Site procedures. No specific on-site routing was considered during the analysis of on-site transportation impacts.

A-7.2 Incident-Free On-Site Transportation

The models used for on-site incident-free transport impacts use primarily the number of trips, distance traveled, and material transported to estimate impacts. It is assumed that materials to be shipped off-site also are transported on-site for treatment, certification, and preparation for off-site transport. Therefore, all off-site trips are assumed to involve an additional on-site transfer. For non-cargo related impacts that depend only on the distance traveled, all on-site trips are assumed to be round trips. Estimates of on-site distances were intended to be the upper bounds of reasonable averages rather than bounding distances. Average travel distances for different types of material transfers were calculated from information gathered for air-quality impacts assessment and from Site knowledge.

For analytical purposes, on-site transportation activities may be divided into two types: 1) transportation related to identified, major activities and 2) those related to routine Site activities that are not specifically identified and scheduled. On-site movement of environmental restoration material and consolidation of low-level waste for shipment off-site are examples of the first type of activity. Examples of the second type of activity include Protective Force operations and use of government-owned vehicles to move materials or personnel throughout the Site.

For identified activities, the basic difference between the *Baseline* and *Closure* cases is the number of transfers made for each type of material and destination. For each type of material transferred, the basic method of calculating the impacts for the different alternatives was to calculate the impacts of a single trip and multiply the impacts by the number of trips of that material.

For specifically identified activities, the impacts are estimated based on the amount and type of material to be transported, number of trips required, and average distance of the expected trips. Site activities specifically addressed include environmental restoration activities; DD&D activities; economic development activities; treatment, storage, and disposal activities involving low level, low-level mixed, TRU, TRU-mixed, hazardous, TSCA, and sanitary wastes; and movement of residues and SNM.

A-7.2.1 Incident-Free Transportation Risk Assessment Methodology

The existing transportation models used in the DOE system are based on over-the-road statistics applicable to off-site transportation of materials. These are of limited value for on-site transportation activities because of differences in traffic density, vehicle speed limitations, and limited access to on-site roadways by members of the public. Site-specific analyses were developed for on-site transportation.

VEHICLE-RELATED IMPACTS. Human health impacts from incident-free on-site transportation include those that are not related to the cargo or purpose of the trip, including those due to tailpipe emissions, fugitive dust stirred up by vehicle movement, and other particulate material released to the air from wear of tires and brakes. These impacts are reported as the number of individuals who may die from cancers developed from inhaling these materials. Because the cancers may take many years to develop, they are called latent cancers. The impacts are reported as latent cancer fatalities.

Cargo-independent impacts are not specific to any identifiable group. That is, they do not impact workers directly involved with the transportation activities more than other personnel on the Site. The latent cancer fatalities reported are for the population as a whole without defining the geographical extent of the impact.

Cargo-independent-related impacts from tailpipe emissions, fugitive dust, and tire particles were estimated by Rao (Rao 1982) based on truck transport distances in an urban environment. This model estimates the number of excess latent cancer deaths per vehicle mile. All on-site movements were assumed to occur within an urban environment. Impact estimates based on Rao's work have been widely accepted by DOE in the past. However, because of changes in automotive engines, fuel mixtures, and transportation speeds, the impacts estimated from this model are probably high. They are used in this analysis for lack of other accepted models based on more current vehicle emissions data.

The number of latent cancer fatalities associated with a group of transfers was calculated by multiplying the number of trips by the average distance per trip times the risk factor of 1.6×10^{-7} latent cancer fatalities per mile as estimated by Rao (Rao 1982).

CARGO-RELATED CHEMICAL IMPACTS. During the transport of hazardous or toxic materials, there should be no significant release of chemicals due to packaging requirements. Failure of the packaging is evaluated in the accident section A.7-3.

CARGO-RELATED RADIOLOGICAL IMPACTS. Likewise, during the transport of radioactive materials, there should be no significant release due to packaging requirements. Failure of the packaging is evaluated in the accident section, A-7.3. However, there are impacts to workers from external radiation exposures from the cargo. On-site transportation impacts from radioactivity are reported for workers directly involved in movement of material. The transportation impacts include vehicle drivers but do not include other individuals who may load, unload, inspect, or otherwise handle the cargo unless they are also directly involved with the movement of material outside of buildings or other structures.

The impacts are also reported as exposures to the maximally exposed individual for other on-site personnel not involved in transportation activities (co-located workers). This is defined as an individual who is located 10 feet from the roadway for every transfer made on-site. While this is physically improbable, the assumption is made as a bounding condition of exposure of individuals on-site. The exposure is reported in rem and also converted to excess cancer fatalities.

Collective doses could be calculated for all personnel on-site or even for all personnel within a 50-mile radius of the Site. The very low risks calculated for the maximally exposed co-located worker and the rapid decrease in exposure with increasing distance from the truck route indicate that such collective risk would not be substantial.

Radiation dose estimates were based on a reasonable estimate for the transport index[2] of either a single package of radioactive material or the transport vehicle.

For transportation of residues, external doses to workers handling and transporting drums were calculated by applying an average drum dose rate at 3 feet of 1.5 mrem/hr. Because the majority of movement activities are performed using mechanized equipment (lifts and dollies), it is assumed that a worker will be, on average, 0.5 meters from the drum during routine activities. Use of the inverse square rule yields a 0.5 meters dose rate of 6 mrem/hr, which is applied to all calculations involving drum handling.

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[2]The transport index is defined as the highest dose rate in millirem per hour at 3 feet from an individual package or 3 feet from accessible surfaces of a closed vehicle.

Exposures to workers and other on-site personnel were calculated using line-source (l/r) approximations, given their relative proximity to the radiation sources. No credit was taken for attenuation of radiation by air or intervening structures. Drum handling was assumed to expose the workers to the drum handling dose rate for one-half of the 50 minutes required to load/unload a truck. Because loading and unloading activities would occur adjacent to multiple drums, it was further assumed that the crew members would also be exposed to an average background dose equal to the individual drum handling value for the full loading/unloading time. For this CID assessment, exposures to the crew members and to other on-site personnel while the shipment is in transit were calculated using the shipment transport index[3]. The transport index values were estimated using the average drum dose rate and assuming that the outer row of 18 drums would primarily contribute to personnel exposures and resulted in transport index values of 6 mrem/hr (EG&G 1992g).

During the 10-minute transit time, the two drivers are exposed at the calculated transport index value for the truck.

Doses to other on-site personnel were calculated using the dose rate at 10 feet from the roadway using the transport index value calculated for the truck. The line-source approximation (l/r) for exposure at 10 feet from the truck is 30% of the transport index value. The dose to the maximally exposed individual is the dose rate at 10 feet from the truck times the length of time required for the truck to pass a given point moving at 5 miles per hour.

Calculations for on-site movement of wastes were performed the same way as for residues except the average dose rate at 3 feet is 4 mrem/hr (EG&G 1992g).

Environmental restoration waste transport calculations used a dose rate of 0.05 mrem/hr at 3 feet from the transport vehicle. Only the transit time exposures are calculated for the drivers.

Table A-7 shows the transport index values for each type of material and the resulting single-trip doses for the transportation workers and co-located workers.

Table A-7. On-Site Transportation Doses

Material	Transport Index (mrem at 3 ft.)	Single Trip Dose Workers (mrem/trip)	Other On-Site Personnel (mrem/trip)
Residues	6	17	3×10^{-3}
Radioactive Waste	4	11	2×10^{-3}
Environmental Restoration Wastes	0.05	0.02	3×10^{-8}

The on-site transfer of material to Building 707 for thermal stabilization and repackaging as part of SNM consolidation activities is estimated to result in worker doses of 0.8 person-rem per year (DOE 1994p) for the 7-year duration of those activities (DOE 1995l). For computational purposes, it is assumed that movement of stabilized material from Building 707 to storage will result in a similar worker exposure. Exposures to other on-site personnel were estimated from the ratio of worker to other personnel doses for other on-site radioactive material transfer activities.

[3] *The transport index is not used for routine on-site transfers, but was used as a basis to estimate exposures to personnel for this assessment.*

The modeling of non-specific government vehicle use assumes the use to be proportional to the number of employees on-site. The number of governmental vehicle miles for the base year was estimated based on 1994 data. For the *Closure* Case, this was multiplied by the ratio of the number of on-site employees during the base year to the average number of employees over a 10-year period. The total number of miles estimated for the annual average and the 10-year period was multiplied by the latent cancer fatalities risk factor to calculate the number of excess latent cancer fatalities. The latent cancer fatalities risk factor for government vehicles was calculated as an average of the latent cancer fatalities risk factors for trucks and light duty vehicles (automobiles) weighted by the total number of miles recorded for each type of government vehicle during the base year.

A-7.2.2 Transport Scenario

Calculations of transport are based on total trips during the 10-year span of the analysis. For the *Closure* Case, all impacts are presented as 10-year cumulative totals, then averaged to present an annual estimate of potential consequences and risks.

Because both the worker and other on-site personnel impacts are stated as hypothetical situations, no specific routing is used in the on-site analyses. However, the results of a specific routing performed for the analyses of air quality impacts were used to establish the average trip length (e.g., 8 miles) for on-site transport.

A-7.2.3 Incident-Free Transportation Impacts

VEHICLE-RELATED IMPACTS: Vehicle related impacts were calculated for each alternative for on-site transportation involving government vehicles, radioactive wastes, environmental restoration wastes, residue consolidation, SNM consolidation, and sanitary waste. All risks are stated as average annual totals for the 10-year analysis period. Tables A-8 and A-9 present the individual latent cancer fatality risks for each activity and the total consequences from all activities combined for the *Baseline* and *Closure* Cases. For the *Baseline* Case, the risk is 2.9×10^{-1} LCF/yr, which is dominated by the non-specified government vehicle usage. For the *Closure* Case, the risk reduces to an annual average of 1.8×10^{-1} LCF/yr, which is still dominated by the non-specified government vehicle usage by a smaller workforce.

CARGO-RELATED IMPACTS (RADIOLOGICAL). Cargo-related impacts from incident-free transportation were calculated for on-site movement of radioactive waste, environmental restoration waste, residue consolidation, and SNM consolidation. The impacts were calculated both in terms of cumulative dose over the 10-year period and the excess latent cancer fatalities estimated for those cumulative doses, as well as annual averages. Doses and risks are shown for both transportation workers and other Site personnel assumed to be located 10 feet from the roadway for all shipments over the 10-year period. Tables A-10 and A-11 present the total dose and excess latent cancer fatalities for each activity and the total dose and excess fatalities for all activities combined for the *Baseline* and *Closure* Cases. These consequences (and risk) for the *Baseline* Case are dominated by radioactive waste transfers and SNM consolidation. The annual average consequences (and risk) for the *Closure* Case is about 50% higher than the *Baseline* Case, and is dominated by the same two activities.

CARGO-RELATED IMPACTS (CHEMICAL). For routine operations, cargo-related nonradiological risks are not calculated, because no substantial health concerns are identified during routine transportation. Packages used for shipping hazardous wastes have been specified by the DOT and have been assumed to preclude any substantial exposure to workers or the public during routine, incident-free hazardous waste transport.

Table A-8. On-Site Incident-Free Transportation Vehicle-Related Impacts–*Baseline* Case

Activity	Latent Cancer Fatality Risk Factor	Average Trip Distance (Miles)	Trips/yr	Total Distance (Miles)	Latent Cancer Fatalities	Annual Risk (LCF/yr)
Government Vehicles	1.5×10^{-7}			1,912,902	2.8×10^{-1}	2.8×10^{-1}
Radioactive Waste	1.6×10^{-7}	8	416	3,224	5.3×10^{-4}	5.3×10^{-4}
Residues	1.6×10^{-7}	8	19	151	2.4×10^{-5}	2.4×10^{-5}
Environmental Restoration Waste	1.6×10^{-7}	8	152	1,213	1.6×10^{-4}	1.6×10^{-4}
Sanitary Waste	1.6×10^{-7}	8	1,037	8,297	1.3×10^{-3}	1.3×10^{-3}
SNM Consolidation	1.6×10^{-7}	8	24	141	2.3×10^{-5}	2.3×10^{-5}
Total					$\mathbf{2.9 \times 10^{-1}}$	$\mathbf{2.9 \times 10^{-1}}$

Table A-9. On-Site Incident-Free Transportation Vehicle-Related Impacts–*Closure* Case

Activity	Latent Cancer Fatality Risk Factor	Average Trip Distance (Miles)	Trips/yr	Total Distance (Miles)	Latent Cancer Fatalities	Annual Risk (LCF/yr)
Government Vehicles	1.5×10^{-7}			937,831	1.4×10^{-1}	1.4×10^{-1}
Radioactive Waste	1.6×10^{-7}	8	673	5,383	8.6×10^{-4}	8.6×10^{-4}
Residues	1.6×10^{-7}	8	19	151	2.4×10^{-5}	2.4×10^{-5}
Environmental Restoration Waste	1.6×10^{-7}	8	4360	34,880	5.6×10^{-3}	5.6×10^{-3}
Sanitary Waste	1.6×10^{-7}	8	1,034	8,268	1.3×10^{-3}	1.3×10^{-3}
SNM Consolidation	1.6×10^{-7}	6	25	149	2.4×10^{-5}	2.4×10^{-5}
Cap Construction	1.6×10^{-7}	6	36,600	216,000	3.5×10^{-2}	3.5×10^{-2}
Total					$\mathbf{1.8 \times 10^{-1}}$	$\mathbf{1.8 \times 10^{-1}}$

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Table A-10. On-Site Incident-Free Transportation Radiological Impacts–*Baseline* Case

		Total Dose (rem)		Excess Latent Cancer Fatalities	
Activity	**Trips/yr**	**Co-Located**	**Worker**	**Co-Located**	**Worker**
Radiological Waste	416	8.3×10^{-4}	$4.6 \times 10^{+0}$	3.3×10^{-7}	1.8×10^{-3}
Residues	19	5.7×10^{-5}	3.2×10^{-1}	2.3×10^{-8}	1.3×10^{-4}
Environmental Restoration Waste	76	2.2×10^{-9}	1.5×10^{-3}	9.1×10^{-13}	6.1×10^{-7}
SNM Consolidation	24	9.9×10^{-5}	5.6×10^{-1}	4.0×10^{-8}	2.2×10^{-4}
Total		$\mathbf{9.9 \times 10^{-4}}$	$\mathbf{5.5 \times 10^{+0}}$	$\mathbf{4.0 \times 10^{-7}}$	$\mathbf{2.2 \times 10^{-3}}$

Table A-11. On-Site Incident-Free Transportation Radiological Impacts–*Closure* Case

		Total Dose (rem)		Excess Latent Cancer Fatalities	
Activity	**Trips/yr**	**Co-Located**	**Worker**	**Co-Located**	**Worker**
Radiological Waste	673	1.4×10^{-3}	7.4×10^{0}	5.4×10^{-7}	3.0×10^{-3}
Residues	19	5.7×10^{-5}	3.2×10^{-1}	2.3×10^{-8}	1.3×10^{-4}
Environmental Restoration Waste	2,180	6.5×10^{-8}	4.4×10^{-2}	2.6×10^{-11}	1.7×10^{-5}
SNM Consolidation	25	1.2×10^{-4}	7.0×10^{-1}	4.9×10^{-8}	2.8×10^{-4}
Total		$\mathbf{1.5 \times 10^{-3}}$	$\mathbf{8.5 \times 10^{0}}$	$\mathbf{6.1 \times 10^{-7}}$	$\mathbf{3.4 \times 10^{-3}}$

A-7.3 On-Site Transportation of Materials Under Accident Conditions

This section addresses a bounding accident associated with the transfer of radioactive materials on-site. An accident is considered bounding if no reasonably foreseeable accident can be found with greater consequences. An accident is reasonably foreseeable if the analysis of occurrence is supported by credible scientific evidence, is not based on pure conjecture, and is reasonable (40 CFR 1502.22(b)(4)).

The risk from this bounding accident is not a good estimate of integrated risk of all potential transportation accidents that could be estimated using probabilistic risk assessment techniques that would evaluate many scenarios. However, this bounding accident is assumed to represent the risk of on-site transportation accidents for the purpose of comparing the *Baseline* and *Closure* Cases. It is not appropriate to compare this estimate of transportation risk to those presented in Appendix C

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"Accidents," although one can compare the estimates of bounding consequences provided that the stated likelihood of the accident is kept in perspective.

A-7.3.1 On-Site Transportation Risk Assessment Method for Accidents

The risk analysis for potential accidents differs fundamentally from the risk analysis for routine transportation because occurrences of accidents are statistical. The accident risk assessment is treated probabilistically. Accident risk is defined as the product of the accident consequence (dose) and the probability of the accident occurring.

The MACCS computer code was used to assess the radiological impacts of accidents that could occur during on-site transportation activities (Chanin 1993; Kaiser-Hill 1996e). The methodology used for these calculations is the same as the methodology used to estimate the radiological impacts of accidents at fixed facilities located on-site as presented in Appendix C "Accidents." One of the benefits of utilizing a single methodology for the assessment of both fixed facilities and on-site transportation is that it allows a direct comparison of the consequences that could result from these two types of postulated accidents.

The health effects endpoints reported for on-site transportation accidents are the same as the methodology that is used to estimate the radiological impacts of accidents at fixed facilities located on-site. These are: 1) maximal dose to on-site workers assumed to be located at 100 m, 2) maximal dose to an off-site individual, and 3) 50-mile latent cancer fatalities for off-site population.

All doses are calculated as the total committed effective dose with a 50-year commitment period. The effective dose was calculated using International Commission on Radiation Protection Publication 26 tissue weighting factors (ICRP 1977).

The code results are presented as both median values (50th percentile) and 95th percentile (the value corresponding to "worst-case" meteorology, expected to be exceeded only 5% of the time in a given year). All of the results are conditional on the occurrence of the specified accident.

Point estimates of societal risk (latent cancer fatalities/year) are defined as the accident frequency (events/year) multiplied by the resultant dose (person-rem), and then multiplied by the latent cancer fatality risk factor for the target population (either worker or public). Doses to transport drivers were not assessed. As a result of the severity of the postulated accident, the transport driver could incur severe injury or fatality from trauma injuries during the accident.

Some of the plutonium buildings are interconnected by enclosed tunnels and passageways allowing inter-building manual transfers of materials. Those that are not connected by tunnel require material to be transported over roads using trucks. On-site transportation of radioactive material is governed by Site administrative controls such as personnel training, enforcing speed limits, restricting the movement of materials to certain hours, providing escorts, blocking routes, and curtailing movement during inclement weather (Kaiser-Hill 1995e).

On-site transportation of special nuclear materials (except LLW and LLMW) will occur using enclosed metal cargo vans that are diesel or gasoline powered. These closed vans follow the most direct routes between buildings. Distances traveled would be less than one mile in most cases. The DOE details requirements for maintaining control and accountability on this material (DOE 1993g). The *On-Site Transportation of Hazardous and Radioactive Materials Manual* (Kaiser-Hill 1995e) and the *Safeguards and Accountability Manual* (Kaiser-Hill 1997) list the procedures necessary to implement these requirements.

Numerous accident scenarios have been considered for potential release of material. The bounding case is for a truck accident involving a post-crash fire. The dynamics of the fire provide both the means to breach a transport and the means for generating and dispersing a substantial quantity of respirable plutonium. The sources of respirable plutonium are plutonium oxide, plutonium metal, and pyrophoric plutonium. Each of these plutonium forms is transported differently and has different release fractions. SNM materials were chosen as the bounding accidents because the cargo maximum inventory is greater than residues and TRU wastes and release fractions are not significantly different.

In the accident under consideration, a fire occurs following a transportation accident involving a vehicle transporting plutonium in approved packages. The chemical energy stored in the vehicle fuel provides the force for release in this case, but not all the heat released goes to the plume. Some of the heat goes to the vehicle, some to the contents of the vehicle, some to the ground, some to the air, and some to the plume. The initial force acting on the material at risk must be estimated to determine the amount and characteristics of the airborne particles generated in an accident. The heat content of the plume released from the accident site substantially affects dispersion parameters and thereby accident consequence estimates. The on-site transportation accidents were postulated to occur near the center of the Site, a distance of 1.5 km to the minimum Site boundary. However, due to the plume rise, the location of greatest dose to a maximally exposed off-site individual is approximately 4.4 km, as discussed in Appendix C "Accidents."

A-7.3.2 Accident Condition Impacts

To evaluate accident risk, there are three basic components which must be described. *First*, an accident scenario must be developed. *Second*, the likelihood describes how often the scenario is expected to occur. *Third*, the consequences for undesired results of the source term (what is released, how much, what form it takes) must be defined and then its dispersion predicted. From the exposure caused by a release, a dose is calculated, and that dose is related to a health effect (i.e., latent cancer fatality).

These accident risk components are discussed further in the following text.

Potential Accident Scenarios Considered

Several accident scenarios were considered for radioactive material transfer and loading/unloading accidents that would result in a release of material:

- Drop or puncture of a radioactive material package during loading or unloading of a transfer vehicle,
- Spill of radioactive material from an improperly sealed package during loading/unloading or transfer,
- A criticality due to improper filling or accumulation/placement of fissionable material packages for transfer, or due to a gross change in geometry following a collision, a fire involving a vehicle that is transferring a full load of radioactive material packages,
- An explosion involving a vehicle that is transferring a full load of radioactive material packages, and
- A collision involving a vehicle that is transferring a full load of radioactive material packages.

The first accident considered (a possible combination of the first two above) is the dropping of a package that would result in a spill while loading or unloading a truck. Since all packages used at the Site are required to withstand at least a 4-foot drop without loss of contents and since the packaging with SNM involves triple metal containment and two plastic bags, there is little likelihood that material would be released during loading or unloading activities. For residue and TRU waste drums, a release is more likely, but again there are several levels of confinement involving plastic-bagged contaminated items and usually an interior rigid plastic liner. Should a release occur, it's radiological consequences to the public would be bounded by a larger release from the selected bounding accident involving SNM. Accidents involving low level wastes would result in much less radiological consequences and are bounded by the bounding SNM scenario.

Pyrophoric plutonium and plutonium oxides are fissile materials; therefore, there is a potential for a criticality accident during transport. However, the quantity of material in each package and the loading of the packages in a closed van meet strict nuclear material safety limit criteria. In order

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for a criticality to be possible, gross deformation of the packages in the closed van must occur. Such deformation would be possible with accidents occurring only at very high velocities. Such velocities are not allowed, nor are they possible given the short lengths of straight road within the protected areas of the Site. Since criticalities are not possible under the conditions present at the Site, they are eliminated (EG&G 1993j).

Spills and criticalities are discussed as non-transportation accidents as evaluated in Appendix C. The remaining scenarios are bounded by the accident described below.

Transport Accident Rates

A major component of accident analysis is the likelihood of an accident occurring. Likelihood describes how often the accident is expected to occur. For this analysis, the likelihood is expressed as a frequency, such as the accident rate (e.g., 5×10^{-5} accidents per mile traveled).

Baseline Case. Under the *Baseline* Case, SNM, residues, and TRU wastes would continue to be stored in existing buildings, with some minor amount of continued SNM consolidation into Building 371 (e.g., from deactivation of Building 779) as discussed in the *Environmental Assessment for Consolidation and Interim Storage of Special Nuclear Material at Rocky Flats Environmental Technology Site* (DOE 1995l). Minimal thermal stabilization of "at-risk plutonium metals and oxides" would continue in Building 707. Plutonium nitrate solutions would continue to be stored in their current locations. These conditions indicate that for the *Baseline* Case, only minimal on-site transportation of plutonium would occur, most of it due to routine transportation of TRU wastes and characterization of residues.

The *Thermal Stabilization Risk Analysis Technical Support Document* (EG&G 1993j) cites a *Baseline* and *Closure* Cases nationwide survey of severe highway and rail accidents involving shipping packages. In this document, it was observed that a fire was required to produce consequences for transportation accidents; information provided suggests that 3% of the normal transport accidents involve relatively severe accidents and fires. This report estimated a Site transportation accident rate of 9×10^{-8} per mile traveled.

For Building 707 thermal stabilization of plutonium oxides (EG&G 1993j), it was estimated that two transfers per year from Building 371 would be required to stabilize the backlog of potentially pyrophoric forms of plutonium (assuming maximum payload). Since SNM was also removed from Building 779 during 1996, an assumption of two additional transfers at maximum loading is made. The actual number of transfers was larger than four, but the cargo inventory was much less than the assumption of maximum capacity. In order to bound the environmental impacts, the maximum quantities are assumed, which are associated with these low probabilities of occurrence. From a risk perspective, the risk for many transfers, e.g., 100 trips, would be the same as for these four trips for the bounding accident because although its frequency would be a factor of 25 times higher (i.e., 100/4), its consequences would be lower by at least the same factor of 25 due to the less truck payload based on the 100 partially-loaded trips instead of 4 fully-loaded trips. The average transport distance was estimated at one mile. Thus, the frequency of transport accidents was calculated as:

$$\text{(Accident Rate)} \times \text{(Average Distance)} \times \text{(Number of Trips)} =$$
$$(9 \times 10^{-8}\text{/mile}) \times (1\text{ mile/trip}) \times (4\text{ trips/yr}) = 4 \times 10^{-7}\text{/yr}$$

Closure Case: For the *Closure* Case, SNM will continued to be consolidated into Building 371, but at a higher rate. The *Safety Analysis in Support of the Environmental Assessment for Consolidation and Interim Storage of Special Nuclear Materials in Building 371* (EG&G 1995j) assumed that there would be approximately 10 transfers per year (at maximum loading) for 5 years, or a total of approximately 50 trips to consolidate all SNM into Building 371. Thus, a factor of 2.5 (i.e., 10/4) increase is applied to the *Baseline* Case estimate to result in a frequency of 1×10^{-6} per year for the *Closure* Case.

Although SNM consolidation should be completed in the next few years, other residue and TRU waste transfer activities will continue to occur. Therefore, this SNM scenario should be a conservative estimate for on-site transfers of residue and TRU waste drums.

Table A-12 provides a summary of the estimated frequency of on-site transportation accidents for the *Baseline* and *Closure* Cases.

Table A-12. On-Site Transportation Accident Frequency Estimates

Case	Annual Transportation Accident Frequency
Baseline Case	4×10^{-7} /yr
Closure Case	1×10^{-6} /yr

Bounding Transportation Accident Scenario

An accident is assumed to occur of sufficient severity to rupture the fuel tank of the truck and produce a fire that eventually involves the entire vehicle. Previous transportation risk assessments have estimated releases from vehicle accidents resulting in a fire involving the cargo (EG&G 1993j, EG&G 1995j; Halliburton 1991). The greatest release is from transferring stabilized oxide (EG&G 1993j; EG&G 1995j). Up to 2.5 kg of stabilized oxide can be packaged in a stainless steel can with a taped lid, doubly wrapped in plastic and tape-sealed, and placed within a Model 8802 Vollrath can with a taped lid. Two assemblies are transferred within a DOT 6C 10-gallon drum with a spacer. The total quantity of stabilized oxide present in a 10-gallon drum could then be as much as 5 kg. Nuclear material safety limits specify a planar array that would allow a transport of 66 drums in the enclosed van[4]. Interior packages in the array within the enclosed van would receive some protection during the accident, so the previous assessments assumed that 50% of the drums are breached as a result of the crash and fire. Based on an airborne release fraction of 1×10^{-3} and 50% respirable, the source term is 82.5 grams of plutonium released to the environment.

If 30 gallons of diesel fuel (the contents of the fuel tank) are fully burned, this pool of fuel will fully burn in approximately 11 minutes. The actual burning time of the truck, which involves other combustibles, may be as long as 30 minutes before the Fire Department extinguishes the fire (EG&G 1995j). A fire of this duration may be long enough and hot enough to cause to release a radioactive plume. It is assumed that only one plume is released and that it has a release height of 10 meters. The heat release rate of the plume is estimated to be 6 million watts (the heat generated from the fuel fire) (EG&G 1995j).

Radiological Impacts

Doses to the maximally exposed individual and the public and co-located workers are presented in Table A-13. All of these results are conditional on the occurrence of the accident and therefore do not account for accident frequency of occurrence. Table A-12 identified the frequency of occurrence of these accidents. Point estimates of societal risk (fatal cancers/year) are defined as the accident frequency (events/year) multiplied by the resultant dose, and then multiplied by the latent cancer fatality risk factor for the target populations. These risk estimates are presented in Table A-13.

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[4] Current criticality safety limits restrict number of packages in an enclosed van to a less number.

Table A-13. Bounding On-site Transportation Accident Involving Plutonium

Scenario	Consequences		*Baseline* Case		*Closure* Case	
	Mean	95th	Frequency (/yr)	Risk (per yr)	Frequency (/yr)	Risk (per yr)
Co-Located Worker Dose (rem CEDE)	7.0×10^{-1}	$3.0 \times 10^{+2}$	4×10^{-7}	2.8×10^{-7}	1×10^{-6}	7.0×10^{-7}
Maximally Exposed Off-site Individual Dose (rem CEDE)	$2.0 \times 10^{+0}$	$8.5 \times 10^{+0}$	4×10^{-7}	8.0×10^{-7}	1×10^{-6}	2.0×10^{-6}
Population Latent Cancer Fatalities (LCF)	$1.2 \times 10^{+0}$	$1.4 \times 10^{+1}$	4×10^{-7}	4.8×10^{-7}	1×10^{-6}	1.2×10^{-6}

A-7.4 Uncertainties and Conservatism in Estimated Impacts

Modeling involves simulating a process that is inherently complex using a fixed and relatively small number of variables. Model uncertainty may result from the general limitations of mathematical models and from a lack of information on model parameters. Where possible, actual data are used, but conservative data are often used where data are unavailable, especially for conditions that are projected to occur in the future.

The assumptions made in performing the CID were intended to yield reasonably conservative dose estimates (e.g., estimates that tend to overestimate rather than underestimate dose) using the best data available at the time of analysis. Accident risk evaluations (both transportation and facility) involve more uncertainty than routine operation exposure risks. Accident risk evaluations involve the use of probabilistic models. Accidents generally have estimated probabilities of occurrence that are much less than one. Therefore, in interpreting the potential risks from transportation accidents, both the estimated probability of occurrence and the estimated consequences are considered. Certain low-probability accidents may have potentially large consequences (e.g., large doses or large number of latent cancer fatalities), but they are not expected to occur often (e.g., probability of less than one-in-one million on an annual basis).

Many of the uncertainties associated with accident analyses impacts are "systematic." This means that many of the modeling and scenario assumptions were applied consistently or systematically throughout the analyses. Therefore, the "relative" differences in the dose estimates should not be affected by errors associated with these systematic uncertainties.

In the scenario involving plutonium oxide loaded on a truck, several conservatisms were used, including the assumption that the accident involves a vehicle transferring the maximum number of drums, each containing the maximum amount of plutonium oxide and no credit is given for confinement of the release within the transfer vehicle (Halliburton 1991).

In this analysis, four trips per year for the *Baseline* Case and 10 trips per year for the *Closure* Case were postulated. A more realistic assumption is that many transfers per year will occur but at quantities much less than the maximum. Accidents involving those transfers would produce lower consequences (EG&G 1995j), but would have a risk equal to that of the bounding accident. To bound estimates of health effects, the maximum quantities are assumed, which are associated with a low probability of occurrence.

A potential accident is postulated to involve failure of the multiple package seals. However, unless the collision involves a vehicle transporting flammable liquids, a large propagating fire could not occur due to the lack of loose combustibles (an exception would be involvement of combustibles from TRU wastes or residues). The heat generated would be dissipated into the remaining bulk metal in the container and the metal racks/pallets that hold the package would act as a large heat sink.

Probability (or frequency) of occurrence calculations are not precise numbers and generally have uncertainties ranging from a factor of 10 to 100. This is also true for radiological consequence and risk calculations.

Considering that accident source terms have a high degree of uncertainty, every effort was made to select conservative values, i.e., yielding higher consequences, when a range of parameter values was available for consideration. For parameter values that have been standardized, either within the Site or the broader DOE community, standard accepted values have been used for the analysis.

Examples of conservative parameter values are as follows: 1) breathing rates used to calculate inhalation dose corresponds to a moderate physical activity level, chosen by the *Baseline* and *Closure* Cases as bounding, 2) no credit is taken for the shielding effects of buildings or the possibility that emergency response measures would initiate a prompt evacuation of the close proximity region, 3) there are no residences at the Site boundary and it is unlikely that members of the public spend substantial periods of time at that location, and 4) the assumed rate of accidents causing a fire and release was based on off-site transportation statistics.

Certain aspects of the models used and the parameters input to the models increase the uncertainty of the results of the analysis. Most of the concerns are systemic in nature so that while they increase uncertainty of the absolute values of the impacts, the effect on the relative impacts of the alternatives should be minimal. The following elements describe the key areas:

- Values for the latent cancer fatalities per mile are most likely overstated because of the improvements in engine fuel efficiency and changes in fuel mixtures since the data supporting that estimate were gathered.
- Modeling for impacts from vehicle emissions was based on trucks in an urban environment. On-site vehicles include lighter duty vehicles (such as cars or light trucks) that are traveling at lower speeds than in an ordinary urban environment and may spend more time idling than normal urban traffic. Light duty vehicles would tend to emit lower levels of pollutants per mile traveled, but low speeds and increased idling time would be expected to increase the amounts of pollutants emitted per mile. No data exist to estimate the magnitude of these effects.
- Although the Site is assumed to be an urban environment, the population density, limited extent of Site population surrounded by a distinctly rural environment, and local wind patterns and local meteorological conditions may be more representative of suburban conditions for which the Rao model is not applicable. The assumption of urban conditions is most likely conservative.
- Waste and residue characterization for present stockpiles and for waste to be generated in the future, especially environmental restoration waste, is not adequate for an accurate assessment of transportation radiation levels. The estimates used are expected to be reasonable but conservative in that they should bound most transfers.
- The estimate of on-site mileage for government vehicles was based on changes in Site worker population as a rough estimate of Site activity. In the past, the greatest fraction of the government vehicle use has been by the protective force the size of which does not necessarily track with Site activities. Also, the workforce size estimates were available for the first and tenth year for the *Closure* Case, but the average of those figures may underestimate or overestimate the actual size of the workforce.

A-8 Off-Site Transportation Analyses

This section describes the analysis of human health impacts from Site-related transportation activities conducted off-site under both incident-free and accident conditions.

A-8.1 Scope of Assessment

Section A-8 includes considerations of impacts due to the materials being transported, and impacts related only to the movement of vehicles without regard to the material being transported.

A-8.1.1 Site Inventories and Projected Inventories

Table A-14 presents the volumes of material and number of shipments off-site for the *Baseline* and *Closure* Cases. Table A-15 presents the mileage estimated for vehicles involved in transportation activities, for which cargo does not play a substantial role.

Volumes of material to be transported and numbers of shipments on-site are drawn from the analysis for the Draft SWEIS project. The information presented in Chapter 3 of this CID for the various major activities was used to select appropriate estimates. Commuter and nonhazardous material shipments were derived from similar data in the *Site-Wide Evaluation of Transportation Risks for the Rocky Flats Plant* (EG&G 1992e) and data gathered for the economic impact analysis for the CID.

Table A-14. Off-Site Transportation Activities

Material	Source	Destination	*Baseline* Case		*Closure* Case			
			Trips/ yr	Annual Volume (yd^3)	Trips/ yr	Annual Volume (yd^3)	10-yr Trips	10-yr Volume (yd^3)
Low-Level Waste	Operations	Nevada Test Site	57	927	81	1,187	807	11,871
	Operations	Hanford	0	0	0	0	0	0
	Environmental Restoration	Nevada Test Site	0	0	2,404	50,000	24,038	500,000
Low-Level Mixed Waste	Operations	Nevada Test Site	0	0	186	2,731	1,857	27,307
	Operations	Envirocare	36	754	36	754	364	7,537
	Environmental Restoration	Envirocare	0	0	5,510	81,000	55,102	810,000
TRU and TRU-mixed	Operations	Waste Isolation Pilot Plant	0	0	42	479	416	4,785
Residues[1]	Operations	Waste Isolation Pilot Plant	0	0	0	0	0	0
RCRA (hazardous)	Operations	Waste Broker	7	48	7	48	70	483
Sanitary Waste	Operations	Off-site	0	0	1,231	18,106	12,312	181,057
TSCA	Operations	Waste Broker	1	2	1	2	10	20
TSCA (radioactive)	Operations	Hanford	1	4	1	4	10	40
Environmental Restoration Fill	Local Off-Site	On-site	0	0	11,259	144,218	112,58 5	1,442,175
SNM	Operations	Other DOE site (analysis assumes Savannah River)	1	classified	6	classified	63	9.8 metric tons

Table A-15. Off-Site Non-Cargo Related Transportation Mileage

Classification	*Baseline* Case		*Closure* Case			
	Trips/yr	Miles/yr	Trips/yr	Miles/yr	10-yr Trips	10-yr Miles
Commuters	3,400,202	78,034,636	2,252,640	51,698,088	22,526,400	516,980,880
Incoming Environmental Restoration Shipments	0	0	7,914	131,000	79,140	1,310,000
Economic Conversion Receipts	0	0	110	2,370	1,097	23,700
Local Non-Hazardous Shipments	N/A	49,280[1]	N/A	7,052[1]	N/A	70,520[1]

[1]Equivalent miles. See Section A-8.2.2 of this appendix for explanation.

A-8.1.2 Transportation Routes

Commuter travel to and from the Site is described in the *Site-Wide Evaluation of Transportation Risks for the Rocky Flats Plant* (EG&G 1992e). The routes for movement of nonhazardous, nonradioactive material are not specified because there are no cargo-dependent routine or accident impacts associated with these shipments. No routes are specified for hazardous or TSCA materials because the waste broker assumes full control of those materials at the time the material is accepted. The waste is not required to conform to any site-specified routing.

Waste transported off-site from the Site is destined for the Envirocare facility, the Hanford Site, the Nevada Test Site, and the Waste Isolation Pilot Plant. The HIGHWAY model (Johnson 1993) was used to determine the truck travel route and mileage. These routes are illustrated in Figures A-1 through A-4.

Figure A-1. Proposed Mixed Waste Routes from the Site to Envirocare

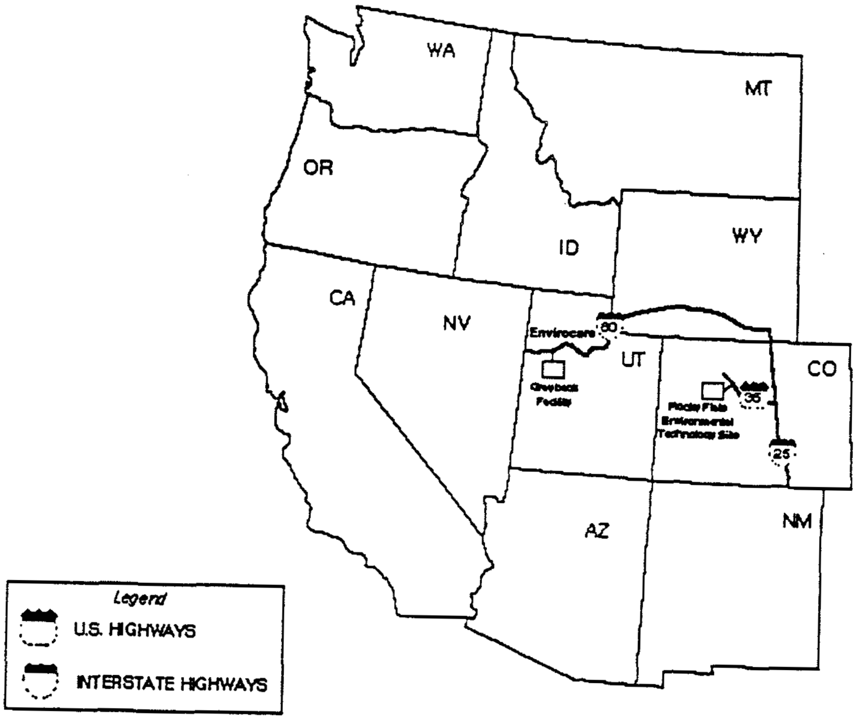

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Figure A-2. Proposed Mixed Waste Routes from the Site to the Hanford Site

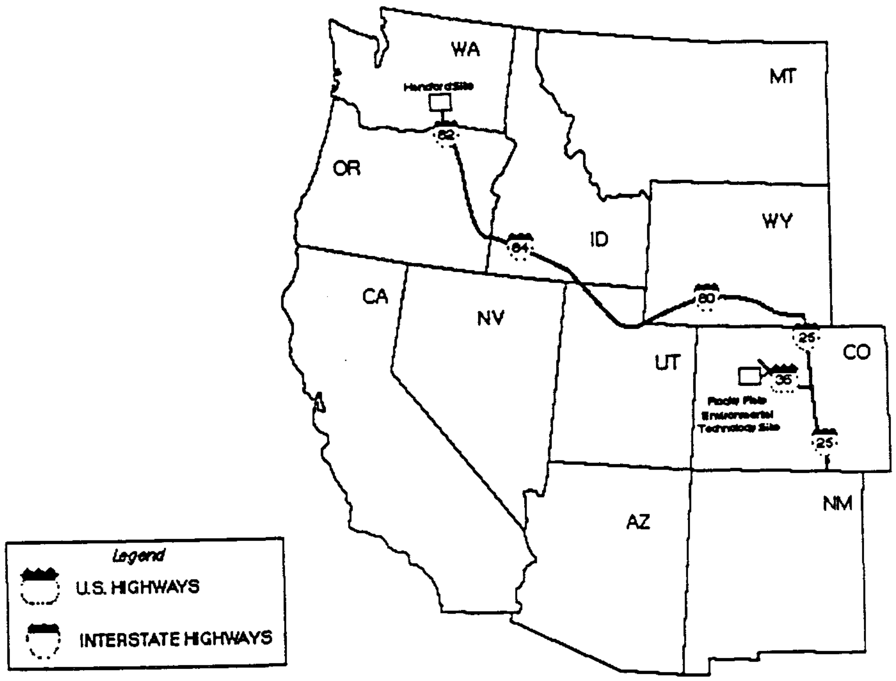


Figure A-3. Proposed Mixed Waste Routes from the Site to the Nevada Test Site

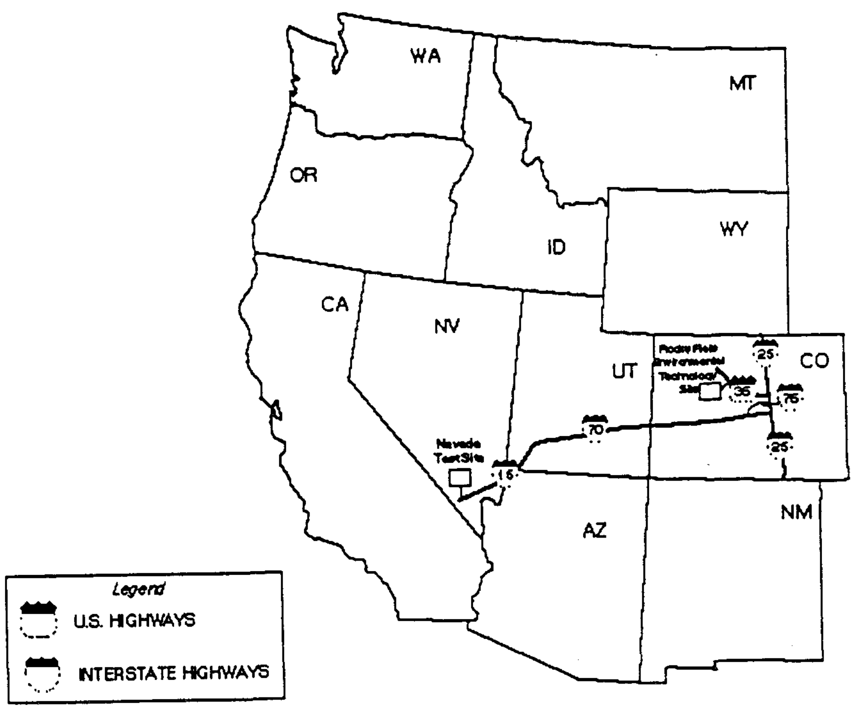
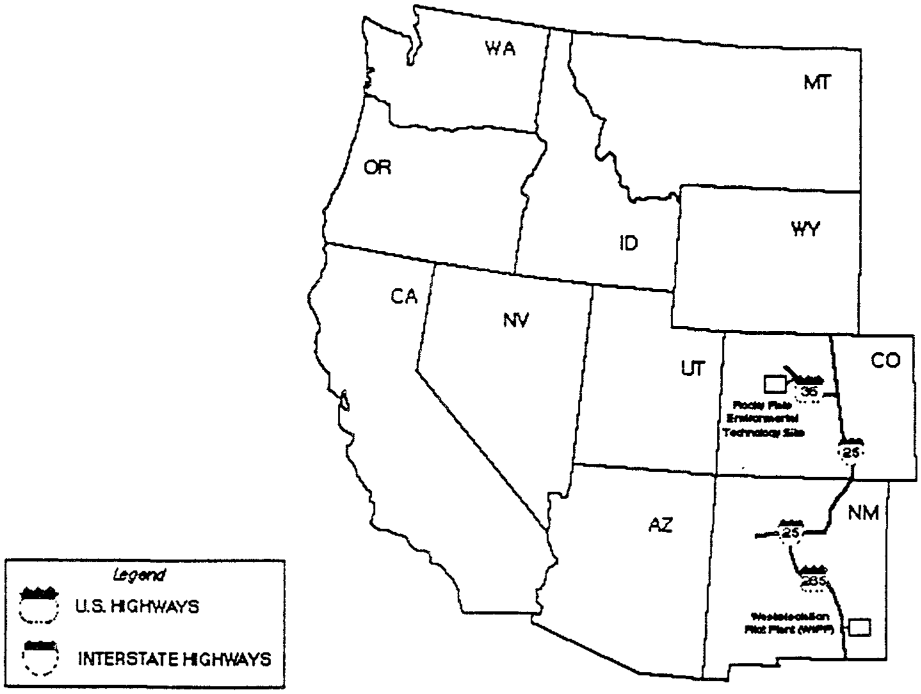


Figure A-4. Proposed Mixed Waste Routes from the Site to the Waste Isolation Pilot Plant



Because the potential sources of material to be processed in the National Conversion Pilot Project in *Closure* Case have not been identified, no specific routing information is available. Specific routing information is also not available for the movement of classified materials.

A-8.2 Incident-Free Off-Site Transportation

A-8.2.1 Incident-Free Risk Assessment Method

The existing transportation models used in the DOE system are based on over-the-road statistics applicable to off-site transportation of materials. The RADTRAN model was used to estimate radiological impacts from incident-free transportation (Neuhauser 1992). Non-cargo related impacts were estimated based on the work of Rao (Rao 1982).

During the transport of hazardous, toxic, or radioactive materials, there is a potential risk from material released from the packaging during incident-free transport. The requirements for packaging make the likelihood of such releases during incident-free transportation small enough that they are not analyzed further in this document. Transportation of radioactive material may also involve exposures from radiation emitted from the package without leakage from the package. The impacts of such exposure are reported in terms of dose, measured in rem for individuals or person-rem for cumulative doses to groups of individuals. To allow comparison to other impacts, the impact of the exposures is also stated in terms of excess cancer fatalities by using internationally recognized conversion factors.

Cargo-independent impacts are not specific to any identifiable group. That is, they do not impact workers directly involved with the transportation activities more than the public. The impacts are reported as latent cancer fatalities. The latent cancer fatalities reported are for the population as a whole without defining the geographical extent of the impact.

Off-site transportation impacts from radioactivity are reported for workers directly involved in movement of material. The transportation impacts include vehicle drivers but do not include other

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individuals who may load, unload, inspect, or otherwise handle the cargo unless they are also directly involved with the movement of material off-site. The concept of co-located workers has no meaning for off-site transportation. Other individuals who may come in contact with the vehicle, such as inspectors, are considered members of the public rather than workers.

The public who may be affected by off-site transportation includes individuals who may live and work along the route on which the material is shipped and individuals who may be present on the transportation route at the same time as the truck transporting the material. Individuals may be pedestrians along the roadway when the transport vehicle passes or individuals in other vehicles traveling either the same or opposite directions or delayed in heavy traffic near the transport vehicle. Other members of the public include individuals working where the transport vehicle stops for such activities as inspection, refueling, or food, and persons who may also be at the same stop during the time the transport vehicle is present. Integrated impacts for all such members of the public are reported as well as the impact on hypothetical persons who may represent the maximum exposure such as someone living near the transportation route or someone working at a stop made by the vehicle.

The models used for off-site incident-free transport impacts use primarily the number of trips, destination, distance traveled, and material transported to estimate impacts.

The principal difference between the *Baseline* and *Closure* Cases is the number of shipments made for each type of material and destination. For each type of material shipped, the basic method of calculating the impacts for the different alternatives was to calculate the impacts of a single shipment or trip and multiply the impacts by the number of trips or shipments of that material. For the *Closure* Case, all incident-free transportation impact estimates are estimated as annual average and cumulative impacts for the 10-year analytical period.

Off-site transportation activities may be divided into two types for analytical purposes: transportation related to identified, major activities and transportation related to routine activities that are not specifically identified and scheduled. For specifically identified activities, the impacts were estimated based on the amount and type of material to be transported, the number of trips required, and the route taken. Off-site shipments are divided into groups based on the source of the material (environmental restoration activities or operations activities that include DD&D, economic development, waste treatment, and residue treatment and disposal), the type of material (LL, LLM, TRU, TRU-mixed, hazardous, TSCA, TSCA with radioactive contamination, non-regulated materials), and the destination to which the material is being shipped (Waste Isolation Pilot Plant, Nevada Test Site, Hanford, Envirocare, Denver Metropolitan Area). Both environmental restoration and economic conversion activities also involve material shipped to the Site.

Cargo-independent impacts from tailpipe emissions, fugitive dust, and tire and brake particles were estimated by Rao (Rao 1982) based on truck transport distances in an urban environment. This model estimates the number of excess latent cancer fatalities per vehicle mile. Impact estimates based on Rao's work have been widely accepted within the DOE system. However, because of changes in automotive engines, fuel mixtures, and transportation speeds, the impacts estimated from this model are most likely high. They are used in this analysis for lack of other accepted models based on more current vehicle emissions data. The estimated off-site non-cargo-related transportation activities are presented in Table A-15 above for the *Baseline* and *Closure* Cases.

The number of latent cancer fatalities associated with a group of truck transfers was calculated by multiplying the number of trips by the urban distance per trip times the risk factor of 1.6×10^{-7} latent cancer fatalities per mile as estimated by Rao (Rao 1982). For commuters, the latent cancer fatalities risk factor used was 1.6×10^{-8} as described in the *Site-Wide Evaluation of Transportation Risks for the Rocky Flats Plant* (EG&G 1992e).

For waste transported off-site, the HIGHWAY model (Johnson 1993) was used to determine the truck travel route and mileage. These routes were determined using the following constraints:

- Links prohibiting truck use were avoided
- State preferred routes were used
- Ferry crossings were avoided
- Non-intersecting interstate access was permitted

The HIGHWAY model was used to determine truck travel mileage and travel distance in rural, suburban, and urban population zones. HIGHWAY has been recently revised to incorporate updated 1990 census data.

The analytical codes or models used for this analysis have been extensively documented in the *Final Supplemental Environmental Impact Statement: Waste Isolation Pilot Plant* (DOE 1990a). RADTRAN was used to calculate radiological risks and was originally developed by Sandia National Laboratories to support preparation of the *Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes* (NRC 1977). This code has undergone almost 18 years of development and is continuing to be refined. RADTRAN 4 (version 4.0.13) (Neuhauser 1992) was used for the current analyses and was accessed using TRANSNET, a Sandia National Laboratories centralized MICRO VAX II computer system.

RADTRAN calculates doses for various population subgroups (e.g., workers, the public) for normal transportation conditions. For the public, it calculates the following doses to people:

- In the vicinity of the transportation vehicle while it is stopped
- Surrounding the transportation route
- Sharing the transportation route with the vehicle

The dose assessment incorporates a point-source approximation for distances between the receptor and the source of more than twice the largest physical dimension of the source. A line-source approximation is applied for exposure distances less than twice the largest package dimension. The RADTRAN code also incorporates features to account for shielding for typical structures in urban and suburban settings. RADTRAN also calculates a hypothetical maximum exposure to an individual who resides along the surface transportation route.

For workers, RADTRAN considers crew members on conveyances. Other workers (e.g., handlers and radiation inspectors) are considered separately. RADTRAN determines the gamma dose to the transportation workers, using a specific source-to-worker characteristic distance for each transportation mode (e.g., truck, rail, or air).

Exposures to individuals residing or working in buildings along the route were determined using RADTRAN Shielding Option 2. This option estimates exposures to individuals in buildings at reduced rates and takes representative credit for shielding benefits afforded by typical building structures found in the three population areas.

Separate analyses were performed for each combination of source, material, and destination appearing in the *Baseline* and *Closure* Cases combined for a total impact. Table A-16 shows the combinations that were used.

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Table A-16. Off-Site Analyses Performed

Material	Source	Destination					
		Nevada Test Site	Envirocare	Hanford	Waste Isolation Pilot Plant[1]	Savannah River Site	Denver Metropolitan Area
Low-Level	Operations	✓					
	ER	✓					
Low-Level Mixed	Operations	✓	✓				
	ER		✓				
TRU	Operations				✓		
TRU-mixed	Operations				✓		
Residues as TRU	Operations				✓		
Hazardous	Operations						✓
TSCA	Operations						✓
TSCA (radioactive)	Operations			✓			
SNM[2]	Operations					✓	

[1]Radiological analysis was taken from the *Final Supplement Environmental Impact Statement: Waste Isolation Pilot Plant* (DOE 1990a) and *Comparative Study of Waste Isolation Pilot Plant Transportation Alternatives* (DOE 1994u). Chemical analysis was developed for the CID.

[2]Analysis was taken from the *Storage and Disposition of Weapons-Usable Fissile Materials Programmatic Environmental Impact Statement* (DOE 1996b).

A-8.2.2 Input Parameters and Assumptions

The basic parameter for calculating incident-free transport vehicle impacts is the total mileage traveled. The number and length of commuter trips and nonhazardous shipments to and from the Denver Metropolitan Area are based on data developed in the *Site-Wide Evaluation of Transportation Risks for the Rocky Flats Plant* (EG&G 1992e) scaled for differences in average Site population. Table A-17 presents the Site workforce levels for each the *Baseline* and *Closure* Cases. The *Baseline* Case is high because it represents the 1994 Site workforce. This is also true for the beginning of the *Closure* Case.

Table A-17. Site Workforce Levels

Job Title/Classification	*Baseline* Case	*Closure* Case	
		Start	End
Engineering & Safety Services	1,318	846	77
Administrative Services	657	422	31
Analytical Services	297	180	12
Support Services	1,062	751	67
Total Site Support	**3,334**	**2,199**	**187**
Office of the President	452	250	0
Environmental Restoration	34	150	0
Waste Stabilization	400	40	25
Waste Management	513	40	25
SNM Management	127	191	100
Economic Development	0	209	0
DD&D	0	400	0
Extended Absences	15	15	0
Subcontractors	1,706	3,005	0
DOE Employees	302	302	12
Total Workers On-Site	6,883	6,800	350
Average Workers On-Site	**6,883**	**3,575**	

Denver Metropolitan Area shipments of nonhazardous material are based on "equivalent miles." The majority of commercial shipments to or from the Site are not exclusive shipments in that the entire capacity of the shipping vehicle was not dedicated to the Site delivery. For accurate projection of transportation mileage directly associated with operation of the Site, an "equivalent shipment" method was used. Shipment analysis was based on an average commercial vehicle cargo capacity of 20,000 pounds (2,500 pounds for parcel-post deliveries). The total weights of all shipments were summed. The totals were divided by the average carrier capacity, resulting in an "equivalent number" of trips and the one-way distance between the shipping region and the Site, which results in the equivalent shipping miles that can be directly associated with Site operation. When a shipment cargo weight exceeded the average 20,000 pounds per vehicle (2,500 pounds per parcel post), the equivalent trip was defined to equal one. The number of equivalent miles used for the bases from which scaling was performed was 6,200 equivalent miles during 1994 when there was an average of 8,660 workers on-site.

Input parameters for RADTRAN were adjusted for each of the combinations shown in Table A-16 above, except for the Waste Isolation Pilot Plant shipments (for which data were already available) and the Denver Metropolitan Area shipments of hazardous and TSCA materials for which RADTRAN is not applicable. Tables A-18 through A-22 show the significant RADTRAN input parameters for each combination. Note, data on these tables are shown in metric units because RADTRAN inputs are all in metric units.

Table A-18. RADTRAN Input Parameters for LLW and LLMW (Operations) to the Nevada Test Site

Parameter	Input Value
Transport Mode	Truck over public highways
Route Distance	1,419.4 kilometers
Route Population Fractions	90.8% in rural zones 7.9% in suburban zones 1.3% in urban zones
Population Density (people/km^2)	2.5 in rural zones 415.7 in suburban zones 2,301.2 in urban zones
Truck Speeds	104.6 km/hr in rural zones 40.3 km/hr in suburban zones 24.2 km/hr in urban zones
Number of Crew	2
Half Boxes Per Shipment	16
Distance from Half Boxes (crew member in transit)	10 meter
Stop Time	0.011 hrs/km traveled
Number of Shipments	1
Persons Exposed While Shipment is Stopped	50
Average Exposure Distance While Stopped	20 meter
Transport Index for Each Shipment	4 mrem/hr

Table A-19. RADTRAN Input Parameters for LLW (Environmental Restoration) to the Nevada Test Site

Parameter	Input Value
Transport Mode	Truck over public highways
Route Distance	1,419.4 kilometers
Route Population Fractions	90.8% in rural zones 7.9% in suburban zones 1.3% in urban zones
Population Density (people/km^2)	2.5 in rural zones 415.7 in suburban zones 2,301.2 in urban zones
Truck Speeds	104.6 km/hr in rural zones 40.3 km/hr in suburban zones 24.2 km/hr in urban zones
Number of Crew	2
Half Boxes Per Shipment	16
Distance from Half Boxes (crew member in transit)	10 meter
Stop Time	0.011 hrs/km traveled
Number of Shipments	1
Persons Exposed While Shipment is Stopped	50
Average Exposure Distance While Stopped	20 meter
Transport Index for Each Shipment	0.05 mrem/hr

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Table A-20. RADTRAN Input Parameters for LLMW (Operations) to Envirocare

Parameter	Input Value
Transport Mode	Truck over public highways
Route Distance	1,041.2 kilometers
Route Population Fractions	90.6% in rural zones 6.6% in suburban zones 2.8% in urban zones
Population Density (people/km^2)	3.2 in rural zones 442.8 in suburban zones 2,249.9 in urban zones
Truck Speeds	104.6 km/hr in rural zones 40.3 km/hr in suburban zones 24.2 km/hr in urban zones
Number of Crew	2
Half Boxes Per Shipment	16
Distance from Half Boxes (crew member in transit)	10 meter
Stop Time	0.011 hrs/km traveled
Number of Shipments	1
Persons Exposed While Shipment is Stopped	50
Average Exposure Distance While Stopped	20 meter
Transport Index for Each Shipment	4 mrem/hr

Table A-21. RADTRAN Input Parameters for LLMW (Environmental Restoration) to Envirocare

Parameter	Input Value
Transport Mode	Truck over public highways
Route Distance	1,041.2 kilometers
Route Population Fractions	90.6% in rural zones 6.6% in suburban zones 2.8% in urban zones
Population Density (people/km^2)	3.2 in rural zones 442.8 in suburban zones 2,249.9 in urban zones
Truck Speeds	104.6 km/hr in rural zones 40.3 km/hr in suburban zones 24.2 km/hr in urban zones
Number of Crew	2
Half Boxes Per Shipment	16
Distance from Half Boxes (crew member in transit)	10 meter
Stop Time	0.011 hrs/km traveled
Number of Shipments	1
Persons Exposed While Shipment is Stopped	50
Average Exposure Distance While Stopped	20 meter
Transport Index for Each Shipment	0.05 mrem/hr

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Table A-22. RADTRAN Input Parameters for Radioactive TSCA to Hanford

Parameter	Input Value
Transport Mode	Truck over public highways
Route Distance	1,847.0 kilometers
Route Population Fractions	91.6% in rural zones 7.4% in suburban zones 1.0% in urban zones
Population Density (people/km^2)	4.5 in rural zones 386.8 in suburban zones 2,281.8 in urban zones
Truck Speeds	104.6 km/hr in rural zones 40.3 km/hr in suburban zones 24.2 km/hr in urban zones
Number of Crew	2
Half Boxes Per Shipment	16
Distance from Half Boxes (crew member in transit)	10 meter
Stop Time	0.011 hrs/km traveled
Number of Shipments	1
Persons Exposed While Shipment is Stopped	50
Average Exposure Distance While Stopped	20 meter
Transport Index for Each Shipment	0.05 mrem/hr

A-8.2.3 Incident-Free Transportation Impacts

Vehicle-related impacts were calculated for off-site transportation, including commuting, shipment of regulated radioactive wastes off-site for disposal, shipment of nonradioactive controlled wastes for treatment or disposal by a waste broker, and removal of other nonhazardous material from the Site. The analysis also includes shipment to the Site of material to be used for environmental restoration activities, material involved in economic conversion activities, and other nonhazardous material. Tables A-23 and A-24 present the off-site incident-free transportation vehicle-related impacts for the *Baseline* and *Closure* Cases. Note that only urban miles are considered to cause these impacts for long-distance waste shipments.

Table A-23. Off-Site Incident-Free Transportation Vehicle-Related Impacts – *Baseline* Case

Source	Latent Cancer Fatality Risk Factor	Average Trip Distance (urban miles)	Number of Trips (per yr)	Total Distance (urban miles)	Latent cancer Fatality Risk
Commuting	1.6×10^{-8}	23	3,400,202	78,034,636	1.3×10^{0}
Local Incoming					
Environmental Restoration	1.6×10^{-7}	12	0	0	0
Economic Conversion	1.6×10^{-7}	22	0	0	0
Denver Nonhazardous	1.6×10^{-7}			2,464	3.9×10^{-4}
Local Outgoing					
RCRA	1.6×10^{-7}	35	7	245	3.9×10^{-5}
TSCA	1.6×10^{-7}	35	1	35	5.6×10^{-6}
Denver Nonhazardous	1.6×10^{-7}			2,464	3.9×10^{-4}
Radioactive					
Operations LL/Nevada Test Site	1.6×10^{-7}	11	58	656	1.1×10^{-4}
ER LL/Nevada Test Site	1.6×10^{-7}	11	0	0	0
Operations LLM/Nevada Test Site	1.6×10^{-7}	11	0	0	0
Operations LLM/Envirocare	1.6×10^{-7}	18	39	659	1.1×10^{-4}
Environmental Restoration LLM/Envirocare	1.6×10^{-7}	18	0	0	0
Operations TSCA/Hanford	1.6×10^{-7}	11	1	12	1.8×10^{-6}
TRU and TRU-mixed/Waste Isolation Pilot Plant	1.6×10^{-7}	19	0	0	0
Residues as TRU/Waste Isolation Pilot Plant	1.6×10^{-7}	19	0	0	0
SNM	1.6×10^{-7}	34	1	10	1.6×10^{-6}
Total					**1.3×10^{0}**

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Table A-24. Off-Site Incident-Free Transportation Vehicle-Related Impacts –*Closure* Case Annual Risks

Source	Latent Cancer Fatality Risk Factor	Average Trip Distance (urban miles)	Number of Trips (per yr)	Total Distance (urban miles)	Latent cancer Fatality Risk
Commuting	1.6×10^{-8}	23	2,252640	51,698,088	8.3×10^{-1}
Local Incoming					
Environmental Restoration	1.6×10^{-7}	12	11,259	135,102	2.2×10^{-2}
Economic Conversion	1.6×10^{-7}	22	110	2,370	3.8×10^{-4}
Denver Nonhazardous	1.6×10^{-7}			3,526	5.6×10^{-4}
Local Outgoing					
RCRA	1.6×10^{-7}	35	7	245	3.9×10^{-5}
TSCA	1.6×10^{-7}	35	1	35	5.6×10^{-6}
Denver Nonhazardous	1.6×10^{-7}			3,526	5.6×10^{-4}
Sanitary	1.6×10^{-7}	50	123	6,155	9.9×10^{-4}
Radioactive					
Operations LL/Nevada Test Site	1.6×10^{-7}	11	81	925	1.5×10^{-4}
Environmental Restoration LL/Nevada Test Site	1.6×10^{-7}	11	2,404	27,562	4.4×10^{-3}
Operations LLM/Nevada Test Site	1.6×10^{-7}	11	186	2,129	3.4×10^{-4}
Operations LLM/Envirocare	1.6×10^{-7}	18	36	659	1.1×10^{-4}
Environmental Restoration LLM/Envirocare	1.6×10^{-7}	18	5,510	99,823	1.3×10^{-2}
Operations TSCA/Hanford	1.6×10^{-7}	11	1	12	1.8×10^{-6}
TRU and TRU-mixed/Waste Isolation Pilot Plant	1.6×10^{-7}	19	42	800	1.3×10^{-4}
Residues as TRU/Waste Isolation Pilot Plant	1.6×10^{-7}	19	420	8,000	1.3×10^{-3}
SNM/Savannah River Site	1.6×10^{-7}	34	6	213	3.4×10^{-5}
Total					**8.7×10^{-1}**

The annual average risk for the *Closure* Case is lower than the *Baseline* Case due to the decreasing workforce resulting in less commuter travel. For both cases, the largest contribution to latent cancer fatalities is commuter travel. However, if these individuals did not work at the Site, they would be commuting to work somewhere else.

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Cargo-related impacts were calculated for shipments involving radioactive materials, including low-level waste, low-level mixed waste, transuranic waste, transuranic-mixed waste, residues shipped as transuranic waste, and TSCA-regulated waste (asbestos) contaminated with radioactive material. Tables A-25 through A-27 present the results of the analysis for the *Baseline* and *Closure* Cases. The tables present the dose for workers and members of the public along the transport route and the excess cancer fatalities estimated from the collective doses. The tables also present the total exposure to the members of the public along the transport route.

For the *Baseline* Case, the risks were dominated by LL waste shipments to the Nevada Test Site. The annual average risk for the *Closure* Case is approximately 3 times higher due primarily to the increased LL and LLM waste shipments to the Nevada Test Site.

Table A-25. Off-Site Incident-Free Transportation Radiation Impacts–*Baseline* Case

Source	Material	Destination	Trips	Collective Dose (person-rem)		MEI Dose (rem)		Excess Cancer Fatalities		Risk of Excess Cancer Fatality	
				Worker	Public	Worker	Public	Worker	Public	Worker	Public
Operations	LL	Nevada Test Site	57	3.7	7.8	1.8	0.0001	1.5×10^{-3}	3.9×10^{-3}	7.3×10^{-4}	3.0×10^{-8}
Environmental Restoration	LL	Nevada Test Site	-	-	-	-	-	-	-	-	-
Operations	LLM	Nevada Test Site	-	-	-	-	-	-	-	-	-
Operations	LLM	Envirocare	36	1.8	3.7	0.9	-	7.0×10^{-4}	1.8×10^{-3}	3.5×10^{-4}	1.9×10^{-8}
Environmental Restoration	LLM	Envirocare	-	-	-	-	-	-	-	-	-
Operations	TSCA	Hanford	1	0.0014	0.01	0.0007	-	5.6×10^{-7}	4.7×10^{-6}	2.8×10^{-7}	6.5×10^{-12}
Operations	TRU and TRU-mixed	Waste Isolation Pilot Plant	-	-	-	-	-	-	-	-	-
Operations	Residue as TRU	Waste Isolation Pilot Plant	-	-	-	-	-	-	-	-	-
Operations	SNM[1]	Various	3	–	–	–	–	-	2.1×10^{-4}	–	–
Total[2]				**5.5**	**11.5**			**2.2×10^{-3}**	**5.9×10^{-3}**		
Maximum						**1.8**	**0.0001**			**7.3×10^{-4}**	**3.0×10^{-8}**

[1]Risk from transportation of SNM was derived from the *Storage and Disposition of Weapons-Usable Fissile Materials Programmatic Environmental Impact Statement* (DOE 1996b). Only a total risk was given which accounts for public and worker. The PEIS analyzed shipment to four sites: Hanford, INEL, Pantex, and Savannah River. The results for Savannah River are used because they are bounding.

[2]Total for public excess cancer fatalities reflects both worker and public fatalities for SNM transport.

Table A-26. Off-Site Incident-Free Transportation Radiation Impacts–*Closure* Case Annual Risks

Source	Material	Destination	Trips	Collective Dose (person-rem)		MEI Dose (rem)		Excess Cancer Fatalities		Risk of Excess Cancer Fatality	
				Worker	Public	Worker	Public	Worker	Public	Worker	Public
Operations	LL	Nevada Test Site	81	5.2	11.0	2.6	0.0001	2.1×10^{-3}	5.5×10^{-3}	1.0×10^{-3}	4.20×10^{-8}
Environmental Restoration	LL	Nevada Test Site	2,404	2.6	17.6	1.3	–	1.1×10^{-3}	8.8×10^{-3}	5.2×10^{-4}	1.6×10^{-8}
Operations	LLM	Nevada Test Site	186	11.9	25.3	5.9	0.0002	4.8×10^{-3}	1.3×10^{-2}	2.4×10^{-3}	1.0×10^{-7}
Operations	LLM	Envirocare	36	1.7	3.7	0.9	–	7.0×10^{-4}	1.8×10^{-3}	3.5×10^{-4}	1.9×10^{-8}
Environmental Restoration	LLM	Envirocare	5,510	4.5	29.8	2.3	0.0001	1.8×10^{-3}	1.5×10^{-2}	9.0×10^{-4}	3.6×10^{-8}
Operations	TSCA	Hanford	1	0.0014	0.01	0.0007	–	5.6×10^{-7}	4.7×10^{-6}	2.8×10^{-7}	6.5×10^{-12}
Operations	TRU and TRU-mixed	Waste Isolation Pilot Plant	42	0.044	0.1	0.02	–	1.8×10^{-5}	5.2×10^{-5}	6.6×10^{-6}	1.1×10^{-10}
Operations	Residue as TRU	Waste Isolation Pilot Plant	420	0.44	1.0	0.2	–	1.8×10^{-4}	5.2×10^{-4}	6.6×10^{-5}	1.1×10^{-9}
Operations	SNM[1]	Savannah River Site	6	–	–	–	–	–	7.7×10^{-3}	–	–
Total[2]				**26.4**	**88.5**			$\mathbf{1.0 \times 10^{-2}}$	$\mathbf{5.1 \times 10^{-2}}$	$\mathbf{5.2 \times 10^{-3}}$	$\mathbf{2.1 \times 10^{-7}}$
Maximum						5.9	**0.0002**			2.4×10^{-3}	1.0×10^{-7}

[1]Risk from transportation of SNM was derived from the *Storage and Disposition of Weapons-Usable Fissile Materials Programmatic Environmental Impact Statement* (DOE 1996b). Only a total risk was given which accounts for public and worker. The PEIS analyzed shipment to four sites: Hanford, INEL, Pantex, and Savannah River. The results for Savannah River are used because they are bounding.

[2]Total for public excess cancer fatalities reflects both worker and public fatalities for SNM transport.

Table A-27. Off-Site Incident-Free Transportation Radiation Impacts–*Closure* Case Risks Over 10 Years

Source	Material	Destination	Trips	Collective Dose (person-rem)		MEI Dose (rem)		Excess Cancer Fatalities		Risk of Excess Cancer Fatality	
				Worker	Public	Worker	Public	Worker	Public	Worker	Public
Operations	LL	Nevada Test Site	807	51.648	109.938	25.824	0.001	2.07×10^{-2}	5.50×10^{-2}	1.03×10^{-2}	4.20×10^{-7}
Environmental Restoration	LL	Nevada Test Site	24,038	26.201	175.898	13.101	–	1.05×10^{-2}	8.79×10^{-2}	5.24×10^{-3}	1.56×10^{-7}
Operations	LLM	Nevada Test Site	1,857	118.848	252.979	59.424	0.002	4.75×10^{-2}	1.26×10^{-1}	2.38×10^{-2}	9.96×10^{-7}
Operations	LLM	Envirocare	364	17.472	36.589	8.736	–	6.99×10^{-3}	1.83×10^{-2}	3.49×10^{-3}	1.89×10^{-7}
Environmental Restoration	LLM	Envirocare	55,102	45.129	298.300	22.564	0.001	1.81×10^{-2}	1.49×10^{-1}	9.03×10^{-3}	3.58×10^{-7}
Operations	TSCA	Hanford	10	0.014	0.095	0.007	–	5.60×10^{-6}	4.73×10^{-5}	2.80×10^{-6}	6.50×10^{-11}
Operations	TRU and TRU-mixed	Waste Isolation Pilot Plant	416	0.441	1.036	0.165	–	1.76×10^{-4}	5.18×10^{-4}	6.61×10^{-5}	1.14×10^{-9}
Operations	Residue as TRU	Waste Isolation Pilot Plant	4,160	4.41	10.36	1.65	–	1.76×10^{-3}	5.18×10^{-3}	6.61×10^{-4}	1.14×10^{-8}
Operations	SNM[1]	Savannah River Site	63	–	–	–	–	–	7.7×10^{-2}	–	–
Total[2]				**259.753**	**874.835**			**1.04×10^{-1}**	**5.14×10^{-1}**	**5.2×10^{-2}**	**2.1×10^{-6}**
Maximum						59.424	**0.002**			2.38×10^{-2}	9.96×10^{-7}

[1]Risk from transportation of SNM was derived from the *Storage and Disposition of Weapons-Usable Fissile Materials Programmatic Environmental Impact Statement* (DOE 1996b). Only a total risk was given which accounts for public and worker. The PEIS analyzed shipment to four sites: Hanford, INEL, Pantex, and Savannah River. The results for Savannah River are used because they are bounding.

[2]Total for public excess cancer fatalities reflects both worker and public fatalities for SNM transport.

A-8.3 Impacts of Off-Site Transportation Materials Under Accident Conditions

The same transportation activities identified in the previous section were analyzed with respect to accident conditions. Both non-cargo-related and cargo-related impacts from accidents were evaluated.

A-8.3.1 Off-Site Transportation Risk Assessment Method for Accidents

Non-cargo-related (or vehicle-related) accident impacts were calculated by multiplying the transport distance by the unit accident fatality rate appropriate for the vehicle type and type of area in which the transportation occurs. Table A-28 presents the fatality rates for individual travel zones (rural, suburban, urban) and weighted average rates for specific destinations. The weighted averages were calculated for specific destinations by summing the product of the fatality rate for each travel zone by the fraction of travel to the given destination that occurs in the travel zone. The fractions of travel by zone were determined using the HIGHWAY code and are shown in Tables A-18 through A-22 for the Nevada Test Site, Envirocare, and Hanford. The fraction of travel by zone for Waste Isolation Pilot Plant was taken from the *Final Supplemental Environmental Impact Statement: Waste Isolation Pilot Plant* (DOE 1990a).

Table A-28. Unit Transportation Accident Fatality Rates

Vehicle Type	Transportation Usage	Fatalities/Mile
Personal Vehicle	Commuter Travel	2.00×10^{-8}
Truck	Denver Metropolitan Area Deliveries	1.04×10^{-8}
Truck	Rural Travel	1.09×10^{-7}
Truck	Suburban Travel	2.69×10^{-8}
Truck	Urban Travel	1.54×10^{-8}
Truck	Waste Isolation Pilot Plant Shipments	9.91×10^{-8}
Truck	Nevada Test Site Shipments	9.15×10^{-8}
Truck	Envirocare Shipments	1.01×10^{-7}
Truck	Hanford Shipments	1.02×10^{-7}

Inhalation is a primary human internal exposure pathway, which results from breathing respirable (< 10 microns) particulate matter. Particulate matter eventually settles out onto the ground where it can expose people to penetrating radiation until the soil is decontaminated or until the radioactive material is weathered or washed away by natural processes. This direct exposure pathway is called "groundshine" exposure. After settling, some fraction of the particles can also be resuspended into the air due to wind or other surface disturbance. These particles can then be inhaled by people as were those in the initial plume and constitute the source term for the resuspension dose pathway initially; particles in the air can also expose people to direct penetrating radiation (aside from inhalation). This pathway is called a "cloudshine" exposure.

The sum of exposures from these pathways constitutes the total exposure. For this analysis, the ingestion pathway (wherein particles settle on plants that are then ultimately consumed by

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people) was not assessed. Development of RADTRAN ingestion parameters (i.e., soil transfer factor, food transfer factor) are currently in draft form. Additionally, based on dose conversion factors for the radionuclides of interest, inhalation exposures result in doses typically one to two orders of magnitude greater than those from ingestion for equal uptakes of radioactive material. Also, any accident resulting in contamination of crops would result in interdiction of those crops (or resultant animal products) prior to consumption by the public.

Calculation of risk from the release of hazardous materials during a transportation accident was performed for a limited set of chemicals selected based on the quantity of the chemical available and the relative toxicity of the chemicals. The screening process is described in the *Site-Wide Evaluation of Transportation Risks for the Rocky Flats Plant* (EG&G 1992e). Impacts calculated from pure chemicals involved in a transportation accident on-site are based on beryllium. Impacts from accidents involving wastes are based on the release of carbon tetrachloride and beryllium. Risks associated with a unit release of each of these materials, calculated in accordance with the EPA's *Risk Assessment Guidance for Superfund, Volume I* (EPA 1989a), are reported in the *Site-Wide Evaluation of Transportation Risks for the Rocky Flats Plant* (EG&G 1992e). The impacts of the release of hazardous chemicals are calculated for the public based on exposures 100 meters from the point of release under representative meteorological conditions (Pasquill Stability Class D).

Per-shipment risks were estimated for TRU waste shipments using the package failure rate, accident probability, and release fractions that were used as RADTRAN model inputs. It was assumed that any damaged drum allows the release of the total volume of volatile gases in the drum headspace (DOE 1990a) and that all gases released from the inner containers are released from the TRUPACT-II shipping vessel during the accident. For low-level waste, low-level mixed waste, and radioactive TSCA shipments, the assumption is made that volatile gases are present in the same quantities as for transuranic waste shipments but that all of the headspace gases are released from any drum damaged in the accident. Release fractions for combustible wastes, contaminated metals, and immobilized sludges have been reported (DOE 1991c) and are used to estimate the release of hazardous material present in solid form.

Model Selection Criteria

The existing transportation models in use in the DOE system are based on over-the-road statistics applicable to off-site transportation of materials. The RADTRAN model was used to estimate radiological impacts from transportation associated accidents. Because RADTRAN does not model the impacts from potential releases of hazardous or toxic materials, a model was developed using similar methodology to RADTRAN.

Modeling of non-cargo-related accident fatalities is described in the *Site-Wide Evaluation of Transportation Risks for the Rocky Flats Plant* (EG&G 1992e) and subsequent Addendum (DOE 1995z).

The analytical codes or models used for this analysis have been extensively documented in the *Final Supplemental Environmental Impact Statement: Waste Isolation Pilot Plant* (DOE 1990a). RADTRAN was used to calculate radiological risks and was originally developed by Sandia National Laboratories to support preparation of the *Final Environmental Statement on the Transportation of Radioactive Material by Air and Other Modes* (NRC 1977). This code has undergone almost 18 years of development and is continuing to be refined. RADTRAN 4 (Version 4.0.13) (Neuhauser 1992) was used for the current analyses and was accessed using TRANSNET, a Sandia National Laboratories centralized MICRO VAX II computer system. RADTRAN incorporates algorithms to produce radiological impacts from accidents exceeding transportation package performance conditions. The code evaluates both internal exposure pathways (i.e., inhalation, resuspension, and ingestion) and external exposure pathways (i.e., cloudshine, groundshine) to project potential accident consequences and risks (probability x consequence) to the general public.

Based on foregoing considerations, RADTRAN was used to determine accident risk/doses (in person-rem per shipment) and waste destination site. The predicted accident risk incorporates the spectrum of incident severities and their associated probabilities of occurrence in each of the population settings (urban, suburban, rural). RADTRAN output also predicts population dose consequences by incident severity category and population setting.

The HIGHWAY model (Johnson 1993) was used to determine truck travel mileage and travel distance in rural, suburban, and urban population zones. HIGHWAY has been recently revised to incorporate updated 1990 census data.

Health Effects Endpoints

For non-cargo-related accidents, the impacts were reported as the number of fatalities estimated for annual averages and the 10-year transport timeframe.

For accidents involving radioactivity, the impacts were calculated as the collective population dose risk stated in person-rem. To place those risks in perspective and allow comparison with other accident risks, the impacts were also converted to excess cancer fatalities by using internationally recognized conversion factors.

For the release of hazardous material, the impacts were estimated as the risk of cancer incidents to an individual remaining 100 meters from the transport route and are reported as excess cancer incidence.

Unlike carcinogenic hazardous chemicals, toxic chemicals do not have an apparent impact when present in less than a threshold concentration. Exposure to these types of chemicals is reported as a fraction of the applicable limit. For members of the public, the estimated long-term air concentration for each chemical is divided by the maximum level to which an individual may be exposed 24 hours a day for 70 years without developing adverse effects. The resulting fraction, called a hazard quotient, is totaled for all reported chemicals and the sum reported as a hazard index. The amount the hazard quotient exceeds 1.0 can serve as an indicator of relative potential for causing harm.

Carcinogenic risk, reported as the excess cancer incidence, is calculated by multiplying the per-shipment risk by the total number of shipments. Noncarcinogenic risk, reported in total fraction of the hazard quotient, is calculated on a single event. Summation of the impacts for multiple shipments is not meaningful because noncarcinogenic effects are considered threshold events and thus are not cumulative.

Receptor Distribution

Off-site transportation accident models do not use receptor distributions based on specific locations. The receptors for non-cargo-related accidents are individuals traveling on the same transportation route or immediately adjacent to the route. The number of individuals exposed to such accidents is modeled as a function of the type of area through which the vehicle is traveling (rural, suburban, or urban population densities.) The differences in number of individuals that may be involved in such accidents as a function of vehicle type and route is reflected in the fatality rates shown in Table A-29.

For the analysis of impacts resulting from an accidental release of hazardous or toxic materials, it was assumed that an unprotected receptor would be located 100 meters from the release point.

Radiological impacts from accidents are calculated as collective doses over the population surrounding the accident site. The receptor population is assumed to be evenly distributed at the densities shown in Tables A-18 through A-22.

Transportation accident impacts are not differentiated for workers (the drivers) and other members of the public.

Input Parameters and Assumptions

The input parameters for vehicle-related fatalities are the total distance traveled for each type of activity and the unit accident fatality rate. The total distance parameter is the same as shown in Tables A-26 and A-27. The unit accident fatality rates are shown in Table A-32. Based on the discussion presented in the *Storage and Disposition of Weapons-Usable Fissile Materials Programmatic Environmental Impact Statement* (DOE 1996b), there has never been an accident involving a vehicle transporting SNM. Therefore, SNM transport has been excluded from this analysis.

Many parameters are input to RADTRAN that affect the accident analysis. Those that vary most according to cargo type and destination include the following:

- Routing distance and fraction of travel by zone
- Accident rates
- Severity category probabilities
- Accident release fractions
- Isotopic mixture and content

Routing distances and fraction of travel by zone are presented in Tables A-26 through A-30. To evaluate accidents, this analysis uses the severity classification scheme and associated probabilities of occurrence as defined in NUREG-0170 (NRC 1977). Accident rates are estimated for travel in each of three population zones (rural, suburban, urban). The severity of possible accidents is estimated according to severity categories. The categories are used to postulate increasingly severe but less likely accidents. The classification scheme uses crush force and fire duration to determine the seriousness of an accident. The crush force may result from either an internal load (e.g., package crushed upon impact by other packages in the load) or a static load (e.g., package crushed beneath vehicle). While fire duration is retained as the thermal parameter, the *Baseline* and *Closure* Cases decided to use puncture and impact speed as the mechanical measure of accident severity.

Table A-29 presents the accident rates and severity category probabilities used in all RADTRAN runs.

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Table A-29. Accident Rates and Severity Category Probabilities

Population Zone	Accident Rate	Severity Category	Probability
Rural	1.370×10^{-7} acc/km	I	0.4620
		II	0.3020
		III	0.1760
		IV	0.0403
		V	0.0118
		VI	0.0065
		VII	0.0006
		VIII	0.0001
Suburban	3.000×10^{-6} acc/km	IX	0.4350
		X	0.2850
		XI	0.2210
		XII	0.0506
		XIII	0.0066
		XIV	0.0017
		XV	0.00007
		XVI	0.000006
Urban	1.600×10^{-5} acc/km	XVII	0.5830
		XVIII	0.3820
		XIX	0.0278
		XX	0.0064
		XXI	0.0007
		XXII	0.0001
		XXIII	0.00001
		XXIV	0.000001

A key parameter for analyzing accidents is the estimated release fraction of radioactive material escaping to the environment. Particulate matter can result from impacts that fracture the radioactive material or from fires that can entrain impact-generated particulate matter, cause off-gassing of volatile materials, or thermally degrade and entrain particulate matter from previously intact material. The release fraction estimates radioactive material released to the environment and available for dispersal downwind from the accident site.

No accident release fractions are available for waste widely accepted in the DOE system. The release fractions used for all waste in this analysis were developed for shipment of waste to the Nevada Test Site (DOE 1991c) and are shown on Table A-30.

Table A-30. Accident Release Fractions

Severity Category	Accident Release Fraction
I	2.65×10^{-5}
II	1.27×10^{-3}
III	4.91×10^{-3}
IV	4.96×10^{-3}
V	4.96×10^{-3}
VI	4.96×10^{-3}
VII	4.96×10^{-3}
VIII	4.96×10^{-3}

No extensive isotopic characterization data are available for waste at the Site. The primary constituents have been identified as americium-241, plutonium-239, and uranium-238, but isotopic concentrations are not well established. Even if current waste characterizations were well known, future waste would not necessarily follow the same patterns.

Therefore, a single set of concentration values was established based on shipping limits for the type of packages that may be used to ship waste. Table A-31 shows the concentrations used for all RADTRAN analyses. The concentrations in waste are based on A2 limits (DOE limits that establish the allowable quantity of radioactive material in a specific package) for americium-241 and plutonium-239 and a reasonable concentration for uranium-238.

Table A-31. Waste Isotopic Characterization for RADTRAN

Radionuclide	Concentration (Ci/Shipment)
Americium-241	1.30×10^{-1}
Plutonium-239	3.20×10^{-2}
Uranium-238	1.60×10^{-0}

Carcinogenic risk and hazard quotients for beryllium and carbon tetrachloride at 100 meters for a one-gram-per-second release rate under representative meteorological conditions (Pasquill stability class D, 5-meters-per-second wind speed) were calculated in the *Site-Wide Evaluation of Transportation Risks for the Rocky Flats Plant* (EG&G 1992e). Using the same methods and data input, unit risk values were also calculated for asbestos. Table A-32 shows the unit risk factors used for the calculations.

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Table A-32. Unit Carcinogenic and Hazard Quotients at 100 Meters for a One-Gram-Per-Second Release

Material	Carcinogenic Risk	Non-Carcinogenic Hazard Quotient
Beryllium	3.32×10^{-5}	N/A
Carbon Tetrachloride	5.14×10^{-7}	3.96×10^{-2}
Asbestos	1.07×10^{-10}	N/A

Chemical release impacts for the Nevada Test Site, Envirocare, and Hanford shipments used the same accident rates, severity probabilities, and release fractions (for particulate) used in the RADTRAN analyses and are shown in Tables A-29 and A-30.

For gas releases, it was assumed that all headspace gases were released from any damaged package. Table A-33 shows the package failure probability (i.e., percent of total number of packages breached by the accident) used for the Nevada Test Site, Envirocare, and Hanford shipments. Although there never has been a release from a transportation accident breaching a DOT Type B container, these probabilities have been established to assess the risk of off-site shipping in numerous NEPA analyses.

Table A-33. Package Failure Probability for Shipments to the Nevada Test Site, Envirocare, Hanford

Severity Category	Package Failure Probability
I	0%
II	1%
III	10%
IV	100%
V	100%
VI	100%
VII	100%
VIII	100%

Because shipments to Waste Isolation Pilot Plant are all in TRUPACT-II packages, which are Type B packages, the release fractions and waste package failure probabilities are different from the Nevada Test Site, Envirocare, and Hanford. The Waste Isolation Pilot Plant release fractions and failure probabilities are in Table A-34. The relative probability of accidents by accident severity is also shown in Table A-34.

Table A-34. Waste Isolation Pilot Plant Accident Severity and Release Fraction Data (TRUPACT II)

Severity Category	Relative Frequency (1 year)	Release Fraction	Package Failure Probability
I	5.5×10^{-1}	0	0%
II	3.6×10^{-1}	0	0%
III	7.0×10^{-2}	8×10^{-9}	30%
IV	1.6×10^{-2}	2×10^{-7}	50%
V	2.8×10^{-3}	8×10^{-5}	70%
VI	1.1×10^{-3}	2×10^{-4}	100%
VII	8.5×10^{-5}	2×10^{-4}	100%
VIII	1.5×10^{-5}	2×10^{-4}	100%

Waste characterization has not been sufficient to estimate typical waste content. Therefore, based on limited headspace sampling reported for the Idaho National Engineering Laboratory (DOE 1990a), the calculation assumed 11.4 grams of carbon tetrachloride in the waste headspace of a single shipment. From discussions with site personnel, it was conservatively assumed that 1 weight percent of the waste shipments is beryllium and that 50 weight percent of asbestos shipments is asbestos.

A-8.3.2 Accident Condition Impacts

Vehicle-related impacts from off-site transportation activities were calculated under accident conditions. Activities included shipment of regulated radioactive wastes off-site for disposal, removal of nonhazardous material from the Site, shipment of nonhazardous, nonregulated material to the Site, and commuting to and from the Site by Site workers and contractors. Tables A-35 through A-37 present the off-site transport vehicle-related impacts from accidents. The impacts are shown as fatalities due to transportation accidents.

Table A-35. Off-Site Transportation Vehicle-Related Accident Impacts–*Baseline* Case

Source	Average Trip Distance (miles)	Number of Trips	Total Distance (miles)	Accident Fatalities
Commuting	22.95	3,400,202	78,034,636	1.6
Local Incoming				
Environmental Restoration	12	0	0	0
Economic Conversion	1,200	0	0	0
Denver Metropolitan Nonhazardous			2,464	0
Local Outgoing				
RCRA	35	7	245	0
TSCA	35	1	35	0
Denver Metropolitan Nonhazardous			2,464	0
Radioactive				
Operations LL to the Nevada Test Site	882	57	50,450	0
Environmental Restoration LL to the Nevada Test Site	882	0	0	0
Operations LLM to the Nevada Test Site	882	0	0	0
Operations LLM to Envirocare	647	36	23,551	0
Environmental Restoration LLM to Envirocare	647	0	0	0
Operations TSCA to Hanford	1,148	1	1,148	0
TRU and TRU-mixed to Waste Isolation Pilot Plant	874	0	0	0
Residues as TRU to Waste Isolation Pilot Plant	874	0	0	0
Total Impacts				**1.6**

Note: For low mileage, a zero value for Accident Fatalities is shown since no traffic fatalities are statistically expected because the calculated value is much less than 1.0.

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Table A-36. Off-Site Transportation Vehicle-Related Accident Impacts–*Closure* Case Annual Risks

Source	Average Trip Distance (miles)	Number of Trips	Total Distance (miles)	Accident Fatalities
Commuting	22.95	2,252,640	51,698,088	1.0
Local Incoming				
Environmental Restoration	12	11,259	135,102	0.0014
Economic Conversion	1,200	110	131,640	0.012
Denver Metropolitan Nonhazardous			3,526	0
Local Outgoing				
RCRA	35	7	245	0
TSCA	35	1	35	0
Denver Metropolitan Nonhazardous			3,526	0
Sanitary	50	123	6,155	0.0001
Radioactive				
Operations LL to the Nevada Test Site	882	81	71,177	0.007
Environmental Restoration LL to the Nevada Test Site	882	2,404	2,120,152	0.21
Operations LLM to the Nevada Test Site	882	186	163,787	0.017
Operations LLM to Envirocare	647	36	23,551	0.0024
Environmental Restoration LLM to Envirocare	647	5,510	3,565,099	0.36
Operations TSCA to Hanford	1,148	1	1,148	0.0001
TRU and TRU-mixed to Waste Isolation Pilot Plant	874	42	36,358	0.0036
Residues as TRU to Waste Isolation Pilot Plant	874	420	363,580	0.036
Total Impacts				**1.7**

Note: For low mileage, a zero value for Accident Fatalities is shown since no traffic fatalities are statistically expected because the calculated value is much less than 1.0.

Table A-37. Off-Site Transportation Vehicle-Related Accident Impacts– *Closure* Case Risks Over 10 Years

Source	Average Trip Distance (miles)	Number of Trips	Total Distance (miles)	Accident Fatalities
Commuting	22.95	22,526,400	516,980,880	10.34
Local Incoming				
Environmental Restoration	12	112,585	1,351,020	0.014
Economic Conversion	1,200	1,097	1,316,400	0.115
Denver Metropolitan Nonhazardous			35,260	0
Local Outgoing				
RCRA	35	70	2,450	0
TSCA	35	10	350	0
Denver Metropolitan Nonhazardous			35,260	0
Sanitary	50	1,231	61,550	0.001
Radioactive				
Operations LL to the Nevada Test Site	882	807	711,774	0.072
Environmental Restoration LL to the Nevada Test Site	882	24,038	21,201,516	2.148
Operations LLM to the Nevada Test Site	882	1,857	1,637,874	0.166
Operations LLM to Envirocare	647	364	235,508	0.024
Environmental Restoration LLM to Envirocare	647	55,102	35,650,994	3.599
Operations TSCA to Hanford	1,148	10	11,480	0.001
TRU and TRU-mixed to Waste Isolation Pilot Plant	874	416	363,584	0.036
Residues as TRU to Waste Isolation Pilot Plant	874	4,160	3,635,840	0.36
Total Impacts				**16.9**

Note: For low mileage, a zero value for Accident Fatalities is shown since no traffic fatalities are statistically expected because the calculated value is much less than 1.0.

For both cases, the largest contribution to accident fatalities is commuter travel, although it decreases for the *Closure* Case due to a smaller workforce. If these individuals did not work at the Site they would be commuting to work somewhere else. The annual average risk for the *Closure* Case increases slightly due to increased shipments of LL waste to the Nevada Test Site and LLM waste to Envirocare.

Impacts were also calculated from materials released from the cargo during off-site transportation accidents. The analysis included radioactive material potentially released from shipments of low-level waste, low-level mixed waste, and TRU-mixed waste. The impacts of the release of hazardous or toxic chemicals were calculated for low-level mixed waste, radioactivity-contaminated TSCA waste[5], and TRU-mixed waste. Tables A-38 through A-40 show the impacts for the *Baseline* and *Closure* Cases. The radiological impacts are shown as the risk of the public receiving a collective dose in person-rem and also the collective risk of excess fatalities from that dose. Radiological accident risk increases for the *Closure* Case annual average due to increased shipments of LL and LLM waste to Nevada Test Site and Envirocare.

For carcinogenic chemicals, the impacts are stated as the risk of cancer incidence to an individual 100 meters from the transport corridor where accidents may occur. This risk increases by approximately two orders of magnitude for the *Closure* Case annual average due to the increased volume of shipping LL wastes.

For toxic chemicals, the impacts are shown as the hazard quotient risk to the same individual member of the public. This hazard quotient is typical in that it incorporates the probabilities of accidents occurring at varying severities and the estimated release factor for each severity. For this reason, it has been called a probabilistic hazard quotient. This risk increases by approximately two orders of magnitude for the *Closure* Case annual average due to the increased shipments of LL and LLM waste to Nevada Test Site and Envirocare. Risk to workers has not been included because under accident conditions where package breach is a concern, the effects of the actual accident on the worker (driver) would be much greater than effects from chemical exposure.

[5]*Noncontaminated TSCA waste is not included for the reasons explained in Section 8.1.2 of this appendix.*

Table A-38. Off-Site Transportation Cargo-Related Accident Impacts–*Baseline* Case

Source	Number of Trips (per yr)	Total Distance (miles)	Radiation Hazards (collective impacts)		Chemical Hazards (member of the public)	
			Accident Dose Risk (person-rem)	Excess Cancer Fatalities	Carcinogenic Risk (Risk of Cancer)	Non-Carcinogenic Risk (Probabilistic Hazard Quotient)
Operations LL to Nevada Test Site	57	50,450	1.69	8.4×10^{-4}	N/A	N/A
Environmental Restoration LL to Nevada Test Site	0	0	0	0	N/A	N/A
Operations LLM to Nevada Test Site	0	0	0	0	0	0
Operations LLM to Envirocare	36	23,551	1.2	6.0×10^{-4}	7.1×10^{-11}	7.8×10^{-8}
Environmental Restoration LLM to Envirocare	0	0	0	0	0	0
Operations TSCA to Hanford	1	1,148	0.032	1.6×10^{-5}	2.4×10^{-16}	N/A
TRU and TRU-mixed to Waste Isolation Pilot Plant	0	0	0	0	0	0
Residues as TRU to Waste Isolation Pilot Plant	0	0	0	0	0	0
Total Impacts				$\mathbf{1.5 \times 10^{-3}}$	$\mathbf{7.1 \times 10^{-11}}$	$\mathbf{7.8 \times 10^{-8}}$

N/A = Not applicable; waste form does not have carcinogenic and/or toxic chemicals.

Table A-39. Off-Site Transportation Cargo-Related Accident Impacts–*Closure* Case Annual Risks

Source	Number of Trips (per yr)	Total Distance (miles)	Radiation Hazards		Chemical Hazards (member of public)	
			Accident Dose Risk (person-rem)	Excess Cancer Fatalities	Carcinogenic Risk (Risk of Cancer)	Non-Carcinogenic Risk (Probabilistic Hazard Quotient)
Operations LL to Nevada Test Site	81	71,177	2.4	1.2×10^{-3}		
Environmental Restoration LL to Nevada Test Site	2,404	2,120,152	70.9	3.6×10^{-2}		
Operations LLM to Nevada Test Site	186	163,787	5.5	2.7×10^{-3}	3.9×10^{-10}	5.4×10^{-7}
Operations LLM to Envirocare	36	23,551	1.2	6.0×10^{-4}	7.1×10^{-11}	7.8×10^{-8}
Environmental Restoration LLM to Envirocare	5,510	3,565,099	181.	9.1×10^{-2}	1.1×10^{-8}	1.2×10^{-5}
Operations TSCA to Hanford	1	1,148	0.03	1.6×10^{-5}	2.4×10^{-16}	0
TRU and TRU-mixed to Waste Isolation Pilot Plant	42	36,358	0.14	7.1×10^{-5}	1.7×10^{-12}	1.3×10^{-7}
Residues as TRU to Waste Isolation Pilot Plant	420	363,580	1.4	7.1×10^{-4}	1.7×10^{-11}	1.3×10^{-6}
Total Impacts				**1.3×10^{-1}**	**1.1×10^{-8}**	**1.4×10^{-5}**

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Table A-40. Off-Site Transportation Cargo-Related Accident Impacts–*Closure* Case Risks Over 10 Years

Source	Number of Trips (per yr)	Total Distance (miles)	Radiation Hazards		Chemical Hazards (member of public)	
			Accident Dose Risk (person-rem)	Excess Cancer Fatalities	Carcinogenic Risk (Risk of Cancer)	Non-Carcinogenic Risk (Probabilistic Hazard Quotient)
Operations LL to Nevada Test Site	807	711,774	23.807	1.19×10^{-2}		
Environmental Restoration LL to Nevada Test Site	24,038	21,201,516	709.121	3.55×10^{-1}		
Operations LLM to Nevada Test Site	1,857	1,637,874	54.782	2.74×10^{-2}	3.89×10^{-9}	5.41×10^{-6}
Operations LLM to Envirocare	364	235,508	11.976	5.99×10^{-3}	7.08×10^{-10}	7.78×10^{-7}
Environmental Restoration LLM to Envirocare	55,102	35,650,994	1,812.856	9.06×10^{-1}	1.07×10^{-7}	1.18×10^{-4}
Operations TSCA to Hanford	10	11,480	0.316	1.58×10^{-4}	2.41×10^{-15}	0
TRU and TRU-mixed to Waste Isolation Pilot Plant	416	363,584	1.414	7.07×10^{-4}	1.70×10^{-11}	1.30×10^{-6}
Residues as TRU to Waste Isolation Pilot Plant	4,160	3,635,840	14.14	7.07×10^{-3}	1.70×10^{-10}	1.30×10^{-5}
Total Impacts				$\mathbf{1.31 \times 10^{0}}$	$\mathbf{1.12 \times 10^{-7}}$	$\mathbf{1.4 \times 10^{-4}}$

A-8.3.3 Rail Analysis for Wastes to be Shipped to Envirocare

A feasible alternative under consideration for shipment of wastes by truck to Envirocare is shipment by train. An analysis was performed to estimate the impacts from train shipment and to compare them to truck shipments on an equal volume basis. Vehicle- and cargo-related impacts from incident free and accident conditions were considered and are discussed below. Train shipments are also a possibility for shipments of TRU wastes to WIPP, but this was not analyzed.

Analysis Methods and Assumptions`

A comparison of vehicle-related impacts between truck and train was derived from existing references and is discussed below. RADTRAN analysis was performed to determine radiological cargo-related impacts. The same method discussed previously in this appendix was used to estimate chemical impacts. It was assumed that the average rail car would transport approximately 31 cubic yards of waste (approximately twice as much as in a truck shipment) and that two rail cars would be sent at once on a train. Input data used for the RADTRAN run are presented below in Table A-41.

Table A-41. RADTRAN Input Parameters for Low-level Mixed Waste Shipments (ER) to Envirocare

Parameter	Input Value
Transport Mode:	Commercial train
Route Distance:	969 km
Route Population Fractions[1]	91.1% in rural zones 8.1% in suburban zones 0.8% in urban zones
Population Density (people/km^2)	7.2 in rural zones 1,095.8 in suburban zones 5,150.0 in urban zones
Number of Crew	5
Half-boxes per shipment (2 rail cars)	30
Distance from cargo to crew	152 m
Stop time per km	0.033 hrs/km traveled
Number of shipments	1
Persons exposed while shipment is stopped	100
Average exposure distance while stopped	20 m
Transport index for each shipment	0.05

For analysis of accident impacts, data regarding accident frequency, severity, and release according to severity were required. These data are presented in Tables A-42 and A-43.

Table A-42. Accident Rates and Severity Category Probabilities for Train Shipments

Population Zone	Accident Rate	Severity Category	Probability
Rural	1.00×10^{-7} acc/km	I	0.356
		II	0.214
		III	0.385
		IV	0.0385
		V	0.00641
		VI	0.000648
		VII	0.000342
		VIII	0.0000641
Suburban	1.90×10^{-6} acc/km	I	0.313
		II	0.188
		III	0.451
		IV	0.0451
		V	0.00338
		VI	0.000163
		VII	0.0000376
		VIII	0.00000313
Urban	1.5×10^{-5} acc/km	I	.0572
		II	0.343
		III	0.0772
		IV	0.0772
		V	0.000514
		VI	0.0000186
		VII	0.00000857
		VIII	0.000000715

Note: Data from *Comparative Study of Waste Isolation Pilot Plant* transportation alternatives (DOE 1994u).

Table A-43. Release Fractions by Severity Category

Severity Category	Accident Release Fraction
I	1.10×10^{-6}
II	4.77×10^{-5}
III	4.46×10^{-4}
IV	4.32×10^{-3}
V	4.32×10^{-3}
VI	4.32×10^{-3}
VII	4.32×10^{-3}
VIII	4.32×10^{-3}

Note: Data from *Nevada Test Site Mixed Waste Disposal Environmental Assessment* (DOE 1991c).

Conclusions

With respect to vehicle-related impacts, emissions and accident fatalities are the two primary impacts. A study performed by the Fernald Environmental Management Company and cited in the *Environmental Impact Statement for the Nevada Test Site and Off-Site Locations in the State of Nevada* (DOE 1996a) compared fuel consumption for a train to fuel consumption for trucks. The results showed that a dedicated train (transports only like waste shipments) could transport the same amount of waste as 239 trucks. The fuel consumed by the train on an hourly basis would be 14% of that consumed by the trucks. Emissions and related health impacts would be similarly lower. On this basis, incident-free vehicle-related impacts are bounded by truck impacts as presented previously in this appendix.

Train transport has also been shown to be safer with respect to accidents. According to the Association of American Railroads, rail transport is five times safer than trucks in terms of accidents per ton-mile when carrying hazardous materials (DOE 1996a). Also, railroads ensure that the shipment is better separated from other traffic and the public. Thus, an accident is less likely to result in fatalities.

Results from the RADTRAN analysis for cargo-related impacts are presented below in Tables A-44 and A-45. For both incident free and accident impacts, the impacts as derived for like volumes of waste, are lower for shipments by train. The impacts presented previously for truck shipments bound the impacts for train transport.

Table A-44. Incident-Free Cargo-Related Impacts for Train and Truck Shipments of LLM to Envirocare

	Cumulative Dose (person-rem)		Maximally Exposed Individual Dose (rem)		Excess Latent Cancer Fatalities		Excess Risk of Latent Cancer Fatality	
Mode	**Worker**	**Public**	**Worker**	**Public**	**Worker**	**Public**	**Worker**	**Public**
Per Shipment Basis								
Truck	8.19×10^{-4}	5.41×10^{-3}	4.10×10^{-4}	1.30×10^{-8}	3.28×10^{-7}	2.71×10^{-6}	1.64×10^{-7}	6.50×10^{-12}
Train	5.00×10^{-3}	5.62×10^{-4}	1.00×10^{-3}	1.19×10^{-8}	2.00×10^{-6}	2.81×10^{-7}	4.00×10^{-7}	5.95×10^{-2}
Equal Volume Basis (4 Trucks:2 Rail Cars)								
Truck	3.28×10^{-3}	2.17×10^{-2}	1.64×10^{-3}	5.20×10^{-8}	1.31×10^{-6}	1.08×10^{-6}	6.55×10^{-7}	2.60×10^{-11}
Train	5.00×10^{-3}	5.62×10^{-4}	1.00×10^{-3}	1.19×10^{-8}	2.00×10^{-6}	2.81×10^{-7}	4.00×10^{-7}	5.95×10^{-12}

Table A-45. Cargo-Related Accident Impacts for Truck and Train Shipments of LLM to Envirocare

Mode	Radiological Impacts		Chemical Impacts	
	Dose (person-rem)	Excess Cancer Fatalities	Cancer Incidence	Noncarcinogenic Hazard Index
Per Shipment Basis				
Truck	3.29×10^{-2}	1.65×10^{-5}	2.03×10^{-12}	2.14×10^{-9}
Train	2.10×10^{-3}	1.05×10^{-6}	2.60×10^{-13}	2.02×10^{-9}
Equal Volume Basis (4 Trucks:2 Rail Cars)				
Truck	1.32×10^{-1}	6.58×10^{-5}	8.12×10^{-12}	8.55×10^{-9}
Train	2.10×10^{-3}	1.05×10^{-6}	2.60×10^{-13}	2.02×10^{-9}

A-8.3.4 Uncertainties and Conservatisms in Estimated Impacts

Certain aspects of the models used and the parameters input to the models increase the uncertainty of the results of the analysis. Most of the concerns are systemic in nature so that while they increase uncertainty of the absolute values of the impacts, the effect on the relative impacts of the alternatives should be minimal. The following elements describe the most significant areas:

- The values for the latent cancer fatalities per mile are most likely overstated because of the improvements in engine fuel efficiency and changes in fuel mixtures since the data supporting the estimate were gathered.
- Commuting miles driven were based on the estimated number of workers on-site, assuming each drives their own vehicle. This is a conservative assumption because it is expected that some carpooling does and will continue to occur.
- The origin or destination of some material being transported to and from the Site is unknown at this time and requires estimates of travel distance.
- All RADTRAN analyses for low-level, low-level mixed, and TSCA waste assumed the waste to be shipped in half-boxes rather than metal drums. The results are generally slightly high for both incident-free and accident conditions using boxes. The shipping form of wastes is not well defined at this time.
- Both waste characterization and release fractions for waste forms are not well defined at this time. Estimates made for such parameters as waste content, headspace gases, and release fractions were intended to be reasonable but conservative; therefore, release estimates in accident situations are expected to be high rather than low.
- The analysis does not include the movement of classified material to or from other DOE sites. From Site experience in the past, the vast majority of such shipments have radiation levels 3 feet from the transport vehicle less than 0.05 mrem/hr, comparable to the radiation levels of TSCA waste shipped to Hanford. Compared to the Hanford data and assuming 10 to 100 times as many shipments per year, the collective excess cancer fatality risks would be on the order of 10^{-4} for workers and 10^{-3} for the public.

A-9 Traffic Impacts Analysis

This section describes the analysis of the impacts of personal vehicles and commercial trucks from the Site on the traffic on local highways in the immediate vicinity of the Site for each alternative. It includes a description of the methodology used to estimate the number of vehicles involved, the sources of data analyzed, and the results of the analyses. No analysis was performed of the traffic impacts on highways outside the immediate vicinity of the Site.

A-9.1 Scope of the Analysis

Activities at the Site add to traffic on local highways by the addition of both personal and commercial vehicles. Site workers use personal vehicles to commute to and from the Site because there is no public transport that serves the Site and the van-pool system available in the past is no longer in operation. Commercial vehicles are used to bring materials and supplies to the Site and to transport material from the Site to other locations. For the *Closure* Case, the analysis estimates the number of vehicles added to local traffic both as an average over the 10-year period and as an average over a single year expected to have the highest traffic impacts. The model used to estimate the highest single year uses methods which make the estimate bounding or worst-case rather than the maximum expected average.

The analysis results are stated as absolute impacts (the average number of vehicles added to local traffic) rather than relative impacts (the change in the number of vehicles on local highways) because recent records of absolute traffic densities on the local highways are not available. Current Site traffic, as represented by 1994 experience, does not add substantially to the traffic on any of the highways serving the Site except during brief periods such as shift changes.

A-9.2 Methodology

The estimate of the number of personal vehicles added to local traffic is based on the estimates of the number individuals working at the Site. The model assumes one personal vehicle per worker. Although it is expected that some of the workers will share rides, estimates of the fraction of workers who share rides is not available. Assuming one vehicle per worker yields a bounding estimate of the number of vehicles added to local traffic.

The number of vehicles added to traffic during the 10-year period of the analysis is based on the average number of workers expected over that time period. The estimate of the number of vehicles during the year of maximum traffic uses the largest anticipated number of workers, regardless of the year in which the maximum occurs. For the *Baseline* and *Closure* Cases, the maximum number of workers was estimated to occur during the first year of the analysis.

Although the employment estimates are made on an annual basis, the average traffic impact is calculated on an average daily basis. Because not all workers commute to the Site each day, the average number of workers commuting each day is estimated using the following formula where the average days worked per year = 247 and average working days per year = 260 (5 days per week, 52 weeks per year) (EG&G 1992e):

$$\text{daily average number of workers} =$$

$$\text{annual average workers} \times \frac{\text{average days worked per year}}{\text{average working days per year}}$$

Quantifying commercial traffic includes both trucking associated with specific activities and general commercial traffic not associated with particular activities. Specific activities include removal of waste from the Site, introduction of clean environmental restoration materials to the Site to replace excavated materials, and shipments associated with economic conversion activities. The average annual number of commercial truck trips is calculated by dividing the number of truckloads required to move the identified amount of material by the ten years included in the analysis.

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The waste management model identifies the number of trips for each year for each waste type. This allows the maximum number of trips in any single year to be determined. The maximum number of trips for each environmental restoration activity is estimated by dividing the total number of trips necessary to move the environmental restoration material by the number of years scheduled for the activity. The number of commercial vehicle trips during the year of maximum traffic is estimated by summing the maximum number of annual trips for each activity, regardless of the year in which the maximum occur. Thus the number of trips in the maximum year is a bounding value and is not likely to be reached in any given year.

Commercial traffic also includes trucking not associated with any of the specifically identified Site activities and consists of shipment of non-hazardous material used in the general operation of the Site and in support of Site activities. The number of such shipments is estimated based on the number of site workers compared to the 1994 *baseline* number of workers and non-waste shipments. The average annual number of shipments is based on the average worker population for each alternative. The number of shipments during the maximum traffic year is estimated using the maximum number of workers for any one year.

The average daily commercial truck traffic density is estimated by dividing the sum of the annual specific and non-specific truck trips by 260, the number of shipping days, assuming shipping activities occur five days per week for 52 weeks a year. Although some shipping activities may be performed for more than five days per week, using this lower number in calculations establishes a bounding estimate of the daily shipments.

A-9.3 Traffic Impacts

Annual vehicle traffic to and from the Site has been estimated for the *Baseline* and *Closure* Cases for both personal vehicles and commercial trucks.

Table A-46 presents the number of commercial truck trips made for the two cases. The activities are shown for both specifically identified activities and for non-specific activities as described above. Also, as described above, the maximum year traffic numbers are bounding estimates which are modeled so the totals for any given year will not exceed the numbers shown in Table A-46.

Table A-46. Commercial Vehicle Traffic for Average and Maximum Years

	***Baseline* Case**	***Closure* Case**	
	Average	**Avg. Year**	**Max. Year**
Incoming Traffic			
Environmental Restoration	0	11,259	12,347
Economic Conversion	0	110	110
Non-Specific, Non-Hazardous	1,690	2,418	2,449
Outgoing Traffic			
RCRA Waste	7	7	7
Non-Specific, Non-Hazardous	1,690	2,417	2,449
Sanitary	0	1,231	1,231
Savannah River	1	10	30
Waste to Other Sites			
Nevada Test Site	57	2,670	3,733
Envirocare	36	5,547	6,661
Hanford	1	1	1
Waste Isolation Pilot Plant	0	42	52
Total	**3,481**	**25,723**	**29,061**

To place the impacts on local traffic in perspective, average daily additions to local traffic are estimated as described above. Table A-47 presents the daily traffic averaged both over the 10-year span and during a maximum traffic year. Average daily traffic calculated from 1994 Site data is also shown in the table.

Table A-47. Average Daily Traffic

	***Baseline* Case**	***Closure* Case**		
	Average	**10-Year Avg.**	**Max. 10-Year**	**1994 Data**
Personal Vehicle	6,539	9,358	9,480	8,227
Commercial Truck	13	99	112	28

Personal vehicle traffic is increased for the *Closure* Case by as much as 50%. The levels during the *Closure* Case are higher than the *Baseline* Case, but not enough to create traffic congestion except during brief periods around shift changes. Truck traffic associated with the *Closure* Case is approximately a factor of 10 higher than the *Baseline* Case. This is high enough for the impacts to be noticeable on the highways in the immediate vicinity of the Site.

The largest contributor to the commercial truck traffic for the *Closure* Case is incoming traffic for environmental restoration. If all the material being brought on-site is obtained at the same location, there also may be traffic impacts in the vicinity of that facility and possibly along the route from the source of material to the Site.

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Appendix B: Human Health and Safety

B-1 Introduction

Appendix B addresses both radiological and nonradiological human health and safety for workers and the public from normal operations. This appendix provides support information for Sections 4.8, "Human Health and Safety," and 5.8, "Impacts on Human Health and Safety." Section B-2 of the appendix addresses routine emissions of radiological pollutants, and Section B-3 describes routine emissions of nonradiological pollutants. It is important to consider both radiological and nonradiological effects because either offer the potential to adversely affect the environment. Impacts from potential radiological and nonradiological accidents are addressed in Appendix C, "Accidents."

B-2 Radiological Human Health and Safety

B-2.1 General

This section provides a brief summary of the technical concepts of radiation and health physics and presents the technical background for understanding the discussion of radiological health impacts.

B-2.1.1 Radiation–Basic Concepts

Although the term "radiation" is very broad and includes energy such as light and radio waves, it is most often used to mean "ionizing" radiation, which is radiation that can remove electrons from atoms and produce charged particles ("ions") in materials that it strikes. Ionizing radiation includes alpha, beta, and gamma radiation; X-rays; and neutrons, each with different characteristics of impacts on the human body. Atoms that emit these kinds of radiation are said to be radioactive.

The effects of radiation on people depend on the kind of radiation and the total amount of radiation energy absorbed by the body. The total energy absorbed per unit quantity of tissue is referred to as absorbed dose. The absorbed dose, after multiplying by certain quality factors and factors that take into account different sensitivities of different types of human tissues, is referred to as "effective dose equivalent." The common unit of effective dose equivalent is the rem.

An individual may be exposed to ionizing radiation externally from a radioactive source outside the body and/or internally from ingesting or inhaling radioactive material. External dose is different from the internal dose in that an external dose is received only during the actual time of exposure to the external radiation source. An internal dose, however, continues to be delivered as long as the radioactive source remains in the body; radioactive decay and elimination of the radionuclide by ordinary metabolic processes decrease the dose rate with the passage of time. The dose from internal exposure is calculated for the 50 years following the initial exposure, and that entire dose is assigned as if it were delivered during the year of the uptake. The assigned dose is called the "committed effective dose equivalent" and is measured in units of rem.

Because of the types of radioactive materials that are used and stored at the Site, the most predominant and hazardous type of radiation at the Site is alpha (particles) from plutonium, which poses an internal exposure hazard. Alpha radiation is not an external exposure hazard because alpha particles do not penetrate the surface layer of the skin to deposit energy into tissues. Plutonium does emit a small quantity of gamma radiation. The handling of kilogram quantities of this material does result in measurable dose to workers. This exposure is controlled through the use of shielding and efficient work practices. However, as plutonium decays, americium, which is a decay product of plutonium and emits gamma radiation, increases in concentration. Therefore, the external exposure hazard at the Site slightly increases over time. Neutrons are also emitted by plutonium but because plutonium emits relatively few neutrons, they do not contribute to as much of the internal hazard as alpha. External neutron exposure dose contributes to worker dose and is considered in estimation of worker dose.

B-2.1.2 Estimating Dose to Radiation Workers

Radiation workers wear thermoluminescent dosimeters, which provide a means of measuring external exposure and assigning dose. Thermoluminescent dosimeters are worn during all radiation work and the dose to which the dosimeter is exposed is representative of the dose to the worker. The thermoluminescent dosimeter's crystalline structure responds to the radiation by "storing" the energy or absorbed dose, which is then "read out" at a later time. Quality factors are then applied to calculate dose in rem to the worker.

Dose data for workers are collected and reported on a periodic basis at the Site. These data are useful both for tracking past exposure and predicting exposure in the future. For this assessment, it was possible to use past dosimetry data to predict future doses for activities that are similar to past activities. For new activities such as decontamination and decommissioning and environmental remediation, it was necessary to model the sources and transport of radioactive materials and to predict exposure of human populations and resulting exposure. This approach was also used to predict doses to the off-site public as described in the following section.

The annual dose limit for radiation workers established by federal law for whole-body exposure is 5,000 millirem or 5 rem (10 CFR 835). In addition to the annual dose limit set by law, an administrative control limit was established by management to ensure that individual and collective radiation dose to workers is maintained well below regulatory limits. The DOE administrative control level is 2,000 millirem or 2 rem per person per year. Exceeding the DOE administrative control limit requires authorization from DOE Headquarters. The administrative control level at the Site for 1996 was 750 millirem. In the future, As Low as Reasonably Achievable program goals will dictate that administrative control limits be set according to work requirements for individual job classifications. This program will result in even lower administrative control levels for many workers (EG&G 1994ee).

B-2.1.3 Estimating Dose to Co-located Workers

Co-located workers are Site workers who do not necessarily perform work that results in radiological exposure, but by their presence at the Site may be exposed to releases that occur. Air is the only pathway that substantially affects the co-located worker. Inhalation of resuspended soil particles is considered as part of the analysis for the air pathway.

Whereas dose to Site radiation workers was determined based on actual bioassay and dosimetry results, dose to the co-located worker was modeled, or calculated, based on air monitoring data as presented in Section B-2.3, "Routine Radiological Emissions and Air Quality Impacts." A very conservative approach to assessing the co-located worker dose was used. This individual was assumed to be identical to the maximally exposed individual, a hypothetical member of the public who is potentially exposed to the greatest dose from Site emissions. CAP88-PC was used to estimate the dose to the co-located worker 100 meters downwind of the emission point and every 100 meters out to the site boundary. A Geographic Information System (GIS) was used to overlay dose maps from each emission point and determine the on-site location of the highest dose. For modeling purposes, two key assumptions were made: 1) that the co-located worker was not wearing a respirator, and 2) that the co-located worker was continually located at the point of maximum contaminant concentration (i.e., for a Site worker not wearing a respirator). The latter assumption is hypothetical and conservative, since no actual worker is likely to be continually present at such a point.

B-2.1.4 Estimating Dose to the Public

The off-site public receives very low doses of radiation from Site emissions and is not monitored for exposure. Therefore, to predict the dose that the public has received from past activities or will receive from future activities, it was necessary to estimate sources of radioactive material, their release to and transport through the environment, and exposure of the public to these materials.

In this assessment, two receptors were analyzed as representative of the public: the maximally exposed individual and the general population within a 50-mile radius of the Site. The maximally exposed individual is a calculated hypothetical person who resides near the Site at a hypothetical location where maximum dose from all pathways is received. The maximally exposed individual demonstrates the bounding scenario but is not truly representative of any individual member of the public. For the maximally exposed individual, all transport media (ground water, surface water, air, soil ingestion, and ground plane irradiation) was evaluated using monitoring and investigation data to determine the maximum possible exposure to an off-site individual. Air is the most important transport mechanism for exposure to the general population, and air modeling was used to estimate the exposure to the public from planned activities or existing sources, although human intake through food and water is also included.

The maximum annual allowable radiation dose to individual members of the public from DOE-operated nuclear facilities is 100 millirem per year (DOE Order 5400.5). It is estimated that the average individual in the United States received a dose of about 350 millirem (0.3 rem) per year from all sources combined, including natural and medical sources of radiation (NCRP 1987a, NCRP 1987b). However, as discussed in Section 4.8.2, "Radiological Health and Safety-Public," the annual natural background radiation dose for Denver-area residents is approximately 418 millirem per year. For perspective, a modern chest X-ray results in an approximate dose of 8 millirem, and a diagnostic hip X-ray results in an approximate dose of 83 millirem. A person must receive an acute (short-term) dose of approximately 600,000 millirem (600 rem) before there is a high probability of near-term death (NAS 1990).

COLLECTIVE DOSE. The collective (or population) dose to an exposed population is calculated by summing the estimated doses received by each member of the exposed population. The total dose received by the exposed population is measured in person-rem. For example, if 1,000 people each received a dose of 1 millirem (0.001 rem), the collective dose is:

1,000 persons x 0.001 rem = 1.0 person-rem

The same collective dose results in a population of 500 people each of whom received a dose of 2 millirem (0.002 rem):

500 persons x 0.002 rem = 1.0 person-rem

B-2.1.5 Health Effects from Radiation

Radiation can cause a variety of ill-health effects in people. Cancer is the predominant ill-

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health effect from the relatively low doses of radiation associated with environmental and occupational radiation exposures. Based on data from laboratory animals and people who have been exposed to radiation (e.g., Nagasaki and Hiroshima survivors and recipients of nuclear medicine therapies), both the increased number of cancers occurring in a population and the increased number of cancer fatalities that result from radiation exposure have been quantified. This assessment used cancer fatalities as its measure of radiological health effects. This effect is referred to as latent cancer fatalities because the cancer may take many years for the cancer to develop and for death to occur after exposure to radiation.

These studies have been used to produce factors that relate the probability of contracting or dying from radiation-related cancer to the dose received. The factor used in this assessment to relate a dose to its effect is 4×10^{-4} latent cancer fatalities per person-rem for workers and 5×10^{-4} latent cancer fatalities per person-rem for individuals among the general population (ICRP 1991b and DOE 1993e). The factor for the general public is higher because of the presence of individuals in the general public (e.g., infants) who are more sensitive to radiation than workers.

These concepts may be applied to estimate the effects of exposing a population to radiation. For example, in a population of 100,000 people exposed only to background radiation (0.3 rem per year), 15 latent cancer fatalities per year would be inferred to be caused by the radiation:

100,000 people x 0.3 rem per year x 0.0005 latent cancer fatalities per person-rem = 15 latent cancer fatalities per year

The calculations of the number of latent cancer fatalities associated with radiation exposure in this assessment often yielded numbers less than one. For example, if a population of 100,000 were exposed as above, but to a total dose of only 0.001 rem, the collective dose would be 100 person-rem, and the corresponding estimated number of latent cancer fatalities would be 0.05. A fractional number of latent cancer fatalities such as 0.05 is a statistical estimate. That is, 0.05 is the average number of deaths that would result if the same exposure situation were applied to many different groups that received the same collective dose. In most groups, no one (0 people) would incur a latent cancer fatality from the 0.001 rem dose each member would have received. In a small fraction of the groups, one latent fatal cancer would result; in exceptionally few groups, two or more latent fatal cancers would occur. The average number of deaths for all groups would be 0.05 latent cancers (just as the average of 0, 0, 0, and 1 is 1/4 or 0.25). The most likely outcome is zero latent cancer fatalities.

B-2.2 Dose Estimates to Radiation Workers

The methodology used to develop worker dose estimates for the *CID* Baseline and Closure cases were described briefly as part of the Chapter 5 impact assessment description. The purpose of this appendix section is to describe the methodologies used in more detail and to provide additional data to substantiate the estimates presented in Chapter 5. Methodologies and results relating to dose estimation for the following areas are presented in this appendix: environmental restoration activities; DD&D activities; the National Conversion Pilot Project; adjustment of doses presented in the SNM and Residue related actions, environmental assessments; and development of dose scaling factors for routine, ongoing operations.

B-2.2.1 Dose Estimates for Environmental Restoration Activities

Environmental restoration (ER) activities have been limited in the past primarily to field investigations, monitoring, and installation of treatment systems as interim remedial actions. Data that quantify worker dose during remedial actions are not available; therefore, it is necessary to estimate the doses received by environmental restoration workers in performing

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any ER activities.

<u>Methodology for Field Worker Dose Estimates.</u> Estimated doses to environmental restoration field workers are calculated from soil concentration data using DOE dose rate conversion factors for external dose from exposure to ground contamination (DOE 1988a). Consistent with assumptions made regarding operations workers, it is assumed that internal and dermal exposure will be managed and minimized using engineered controls and personal protective equipment and will be negligible; therefore, external exposure was the only route considered in this analysis. External dose was calculated using the following equation:

Collective external dose = soil concentration x dose rate conversion factor x number of workers exposed x fraction of time at field location

Conservative soil concentration values were used and were selected as follows. Based on dose conversion factors and soil concentrations used, up to 10 radionuclides were identified as the principal contributors to external dose. Maximum concentrations for one or more of these radionuclides were found on four sites. Doses were calculated for remediation activities for each of the four sites and are presented in Table B-1. Table B-2 provides radionuclide specific detail on this calculation. The specific assumptions applied to each alternative are discussed below.

Additional assumptions were made in calculating worker dose. Based on the staffing requirements of "hot-spot" removals that have occurred on site, it was assumed that 24 people would staff a remediation project full-time. For this staff, only an average of 50% of their work hours would actually be spent on the work site. It is known but not well quantified that soil provides shielding from subsurface deposits of radionuclides. As recommended in *External Dose-Rate Conversion Factors for Calculation of Dose to the Public* (DOE 1988a), a factor of 0.7 was applied to the dose conversion factor to account for this shielding effect. In addition, these published conversion factors reflect continuous exposure over a year; therefore, they were further modified to reflect worker exposure that is limited to work hours on the remediation site.

<u>Methodology for Disposal Site Worker Dose Estimates.</u> Dose estimates for disposal site workers were derived by estimating maximum surface dose rates to which workers would be exposed and multiplying these dose rates by the number of workers and the annual number of hours of exposure. This approach is consistent with the approach used in *Draft Environmental Assessment: Mixed Waste Disposal Operations at the Nevada Test Site* (DOE 1991c). Typical dose rates for Site waste were derived from a section of this environmental assessment that addressed Site waste.

<u>Methodology for Waste Treatment and Packaging Dose Estimates.</u> The waste treatment and packaging operations that would be used for remediation waste are new to the Site. However, it has been shown that dose from operations involving a given waste type is relatively independent of the specific operation. Therefore, it was assumed that all low-level waste operations personnel would receive similar dose. The Building 374 Operations Group 1994 dose was used as the basis for estimating dose for these new operations and was adjusted proportionately according to the number of people that would be required to run the operation. Table B-3 details this calculation for the *CID* Closure Case.

<u>Baseline Case</u>: During the Baseline case minor environmental restoration work was performed. OU-2 trenches T-3 and T-4 were remediated. Approximately 3000 cubic yards of volatile organic compound and radionuclide contaminated soil were excavated and treated using low-temperature thermal desorption prior to re-emplacement in the trench site. Radionuclide concentrations were at low enough levels that no radionuclide remediation was necessary. Radiation exposure to environmental restoration workers was negligible. CAP88-PC analyses were performed before the project to estimate the impact of off-site emissions to a maximally

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impacted individual. Analysis indicated a dose below regulatory thresholds for monitoring or reporting. Emissions measurements taken during the activity do support the initial "below regulatory threshold" conclusion, but were still undergoing analysis at the time this *CID* was completed. Both worker and public dose are bounded by the dose resulting from routine plant operations.

Closure Case: As discussed in the description of the Closure case in Chapter 3, the Site will be remediated to open space land use standards for the buffer zone and industrial land use standards for the industrial area. This end-point would be achieved through completion of closure of each operable unit, either by remediation or determination of no further action. Environmental remediation activities would result in worker dose, primarily from external exposure to ground contaminated with radionuclides. The majority of the waste would be packaged for off-site disposal although some would require on-site treatment. Table B-1 shows the estimated annual worker dose during the various environmental restoration site activities.

Table B-1. Processing and Treatment Activities for Environmental Restoration Waste

Description	Unit Throughput	Volume (cy)	Number of Workers	Collective Annual Dose (person-rem)[1]
Closure Case–No processing or treatment activities to occur				
Closure Case				
Low Temperature Thermal Desorption (4 units)	100 cy/day	791,814	32	1,984
Soil Packaging	50,000 cy/yr	500,000	15	930

[1]Estimation of dose for treatment processes is based on 1994 doses for Building 374 waste evaporator operations; for this process, dose was approximately 62 mrem/person. Annual dose is based on staffing and dose rate assumptions that are consistent with the *Waste Management Programmatic Environmental Impact Statement* (DOE 1995m) and *Draft Environmental Assessment: Mixed Waste Disposal Operations at the Nevada Test Site* (DOE 1991c).

B-2.2.2 Dose Estimates for Deactivation, Decontamination, and Decommissioning Activities

Baseline Case: DD&D activities are beginning at the Site and minimal activities occurred during the Baseline case. Building 889 was decontaminated and decommissioned. The building was demolished and the rubble removed from Site. Building 779 was deactivated and the stored radioactive material was removed from the building. Worker dose and site emissions from both activities are bounded within the routine worker dose and site emissions for the Baseline case.

Closure Case: The following sections describe the DD&D process and the basis and results of estimating worker exposure and dose.

DEFINITION OF THE DD&D PROCESS. Several stages are involved in the process of emptying and leveling a building. To clarify the process that will be considered in development of the worker dose analysis, the following sections provide a set of definitions of a typical process as currently defined at the Site. Only those phases that are relevant to the worker dose analysis (deactivation and decontamination) are described.

Table B-2. Summary of Environmental Restoration Activities and Associated Worker Doses

Remediation Project	Closure Case	
	Description	**Annual Worker Dose (person-mrem)**
ER Site Activities		
OU1	Contaminated soil excavation[1]	2.36E+01
OU2	All IHSSs excavated (OU2)	1.36E+02
	Water treatment	Negligible[2]
OU4	Excavate, package, ship (1-year)	7.14E+01
Total		2.31E+02
Waste Processing Activities		
Low Temperature Thermal Desorption	Process 400 cy/day	1.98E+03
Soil Packaging	Package soil for off-site shipment	9.30E+02
Total		2.91E+03

[1]Assumes 5% of OU1 and OU2 contaminated soil is removed, as an approximation of various soil remediation activities that will occur.

[2]Is a low occupancy process rather than more labor intensive field operation; therefore, worker dose is projected to be negligible.

Table B-3. Estimates of Incremental Dose and Latent Cancer Fatalities for Remediation Workers

Location/ Radionuclide	Maximum Soil Concentration (pCi/g)	Estimated Surface Concentration[1] (micro*Ci/m^2)	Dose-Rate Conversion Factor[2] (mrem*m^2/micCi*yr)	Modified Dose Conversion Factor[3] (mrem*m^2/micCi*yr)	Individual Annual Dose (mrem)	LCF from Annual Dose	Annual Total Project Dose[4] (person-mrem)
Plutonium Zone							
Americium-241	54	2.70E+00	2.99E+00	2.39E-01	6.45E-01	2.58E-07	
Plutonium-239/-240	874	4.37E+01	8.20E-02	6.55E-03	2.86E-01	1.15E-07	
Uranium-233/-234	3.6	1.80E-01	8.07E-02	6.45E-03	1.16E-03	4.64E-10	
Uranium-235	0.7	3.50E-02	1.71E+01	1.37E+00	4.78E-02	1.91E-08	
Uranium-238	3.2	1.60E-01	6.46E-02	5.16E-03	8.26E-04	3.30E-10	
Total					**9.81E-01**	**3.93E-07**	**2.36E+01**
OU2–903 Pad Source Area							
Americium-241	160	8.00E+00	2.99E+00	2.39E-01	1.91E+00	7.65E-07	
Plutonium-239/-240	11000	5.50E+02	8.20E-02	6.55E-03	3.60E+00	1.44E-06	
Uranium-233/-234	55	2.75E+00	8.07E-02	6.45E-03	1.77E-02	7.09E-09	
Uranium-235	2.1	1.05E-01	1.71E+01	1.37E+00	1.43E-01	5.74E-08	
Uranium-238	15	7.50E-01	6.46E-02	5.16E-03	3.87E-03	1.55E-09	
Total					**5.68E+00**	**2.27E-06**	**1.36E+02**
OU4–Solar Evaporation Ponds[5]							
Americium-241	220	1.10E+01	2.99E+00	2.39E-01	2.63E+00	1.05E-06	
Plutonium-239/-240	56	2.80E+00	8.20E-02	6.55E-03	1.83E-02	7.34E-09	
Tritium	329000	1.65E+04	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
Uranium-233/-234	63.4	3.17E+00	8.07E-02	6.45E-03	2.04E-02	8.18E-09	
Uranium-235	2.3	1.15E-01	1.71E+01	1.37E+00	1.57E-01	6.29E-08	
Uranium-238	27	1.35E+00	6.46E-02	5.16E-03	6.97E-03	2.79E-09	
Barium-137m[6]	0.5	2.50E-02	6.11E+01	4.88E+00	1.22E-01	4.88E-08	
Radium-226	6.83	3.42E-01	7.60E-01	6.07E-02	2.07E-02	8.30E-09	
Strontium-89	1.1	5.50E-02	1.36E-02	1.09E-03	5.98E-05	2.39E-11	
Strontium -90	1.1	5.50E-02	0.00E+00	0.00E+00	0.00E+00	0.00E+00	
Total					**2.97E+00**	**1.19E-06**	**7.14E+01**

[1]Surface concentration is estimated using the following equation, which assumes all contamination sampled to a 5 cm depth is found on the surface. Maximum surface concentration (microCi/m^2) = soil concentration (pCi/g) x 1gm/cm^3 x 5 cm x 10^{4} cm^2/m^2 x 1microCi/10^{6}pCi.
[2]Dose conversion factor from DOE *External Dose-Rate Conversion Factors for Calculation of Dose to the Public* (DOE 1988a).
[3]Dose conversion factor modified to reflect worker exposure, assuming worker is in contaminated area 50% of the time and shielding effect of soil of 0.7 and 2,000 hours worked per year.
[4]Assumes a work crew of 24.
[5]Concentrations reflect the highest values for each radionuclide between the surficial and subsurface soils.
[6]Barium-137m is used here instead of Cesium-137 because it is the decay product and has the higher dose-rate conversion factor.

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DEACTIVATION. Deactivation encompasses the removal of radioactive and hazardous sources and other activities determined to reduce the risk and the cost associated with surveillance and maintenance. For this analysis, it was assumed that all readily accessible sources have been removed prior to beginning DD&D. Deactivation activities also include the removal of tooling and classified items and isolation of process equipment from all non-essential utilities as well as removal of remaining accessible nuclear materials. Limited decontamination would occur as required to achieve the end-state criteria defined for deactivation or as the precursor to the decontamination phase.

DECONTAMINATION. Decontamination is the removal of remaining removable contamination and all accessible fixed contamination from the equipment within the facility as well as the facility's structural surfaces. This stage would further reduce the radioactive contamination of the facility by removal of equipment, including gloveboxes and piping, wall and floor coverings, and contaminated concrete surfaces. The decontamination criteria will be based on waste disposal criteria. Decontamination is the final phase that would result in worker exposure to radioactive and hazardous materials.

METHODOLOGY FOR ANALYSIS OF WORKER EXPOSURE AND DOSE. The estimate of dose from DD&D activities is based on the following calculation:

collective worker dose = hours exposed x average dose rate of the area
x number of workers

Two types of information were required to make this calculation: the anticipated staffing requirements for the project and the dose rates that would be anticipated for the different phases of the project. A detailed cost estimate and schedule were prepared for the complete DD&D of Building 779 (EG&G 1995n). This building is representative of a plutonium processing building; therefore, the staffing estimates made could be applied to the generic 100,000-square-foot building. A similar study was performed for tanks (EG&G 1995o) and was used to estimate resource requirements for DD&D of wet processing areas. For the dose rate portion of the equation, radiological protection personnel at the Site assisted with estimating dose rates that would be encountered in different types of processing buildings at different phases of DD&D (EG&G 1995p).

For the Closure case, preliminary cost estimates for DD&D of all Site buildings were used as a basis for estimating worker hours (RMRS 1995b).

Analysis of worker dose focused on deactivation and decontamination, which are equivalent to equipment isolation and removal processes in the cost and schedule projects. Isolation includes removal of alarm and monitoring systems, isolation of electrical systems, removal of support equipment, and isolation and removal of process lines. Removal includes surveys of contamination; decontamination of the interior; removal of lead; installation of tent bag or other radiological containment; removal of Zone 1 ventilation supply and exhaust ducting; removal and size reduction of equipment such as gloveboxes, tanks, and machinery; and removal of radiological containment. In the Closure case, to estimate the amount of time and exposure that would be associated with these activities, it was necessary to define the contents of the generic 100,000-square-foot building being analyzed.

GENERIC BUILDING DESCRIPTION. The generic 100,000-square-foot plutonium building analyzed in this *CID* contains a variety of process equipment, offices, storage space, and locker rooms. Actual plutonium buildings at the Site were each built for a specific function; therefore, each building is unique. The purpose of defining the generic building is to show the process and impacts for the DD&D of a building containing many of the elements that would typically be found in a plutonium building and to provide a basis for estimating the time required for the process and associated exposures. Table B-4 outlines the types of areas in the building, the size of the areas, a description of the equipment in each area, an estimate of the person-hours required to perform isolation and removal, and the dose associated with the deactivation and decontamination phases of the project.

Table B-4. Building Description and DD&D Labor Hours with Radiological Exposure for Generic 100,000 Square-Foot Plutonium Facility

Area Type	Typical Area Content	Equipment Inventory	Total Area in Building (sq. ft)	Person-Hours to Deactivate	Deactivation Dose rate (mrem/h)	Dose from Deactivation Activities (mrem)	Person-hours to Decontamination	Decontamination Dose Rate (mrem/h)	Dose from Decontamination (mrem)	Total DD&D Dose (mrem)
Process Rooms	Gloveboxes, metallurgy equipment	Gloveboxes: 91; X-ray equipment: 5; Hood systems: 20; Various machining tools	36,400	30,184	1.5	22,638	159,865	0.075	5,995	28,633
Mechanical Rooms	Filter plenums, generators		Included in process rooms	N/A	N/A	N/A	9,424	0.075	353	353
Wet Process Rooms (see assumption 4.)	Tanks and piping	Tanks: 99	19,700	17,998	3.0	53,995	30,188	0.150	4,528	58,523
Offices, locker rooms, etc.			43,900	N/A	N/A	N/A	N/A	N/A	N/A	
Totals			**100,000**			**76,633**			**10,877**	**87,509**
Maximum Annual Dose					**25,544**					

Assumptions:
Time estimate is based on generic plutonium-contaminated facility as drawn in Figure B-1; the description of this building was arbitrary, but it is consistent with existing buildings at the Site.
Equipment loadings are based on Building 779 for the glovebox area and an estimated tank density for the wet processing area as determined from a review of Site facility floor plans.
Time estimates include only those activities that are expected to involve exposure to radioactive contamination.
Time estimate of wet processing area decontamination includes assumption that rooms are an average of 525 square feet and decontamination requires 10 days per room with a 6-person crew.
Dose rates are based on calculations made by the Site Radiological Engineering Group (EG&G 1995p).
(Sources: EG&G 1995n, EG&G 1995o)

The generic building configuration was determined in the following manner. A generic plutonium facility at the Site would be expected to house manufacturing areas, which would contain gloveboxes with machining equipment or metallurgical processing equipment and/or wet processing areas, which would contain tanks, piping, and pumps. Therefore, to fully represent the possible types of areas that might be involved in a DD&D project, both types of processing areas were included in the generic building.

The glovebox areas were patterned after configurations in Building 779 because this building contains numerous processing areas and was the subject of a detailed time and cost estimate with respect to complete DD&D. The ratio of process area to total square footage found in Building 779 was applied to the generic building. The overall square footage of Building 779 is approximately 64,000 square feet of which 36,409 square feet (56%) contain process equipment. Therefore, 56% (56,000 square feet) of the generic building is process area of which 36,409 square feet contain glovebox processes and 19,700 contain wet processes. The equipment loadings for the glovebox areas are based on an inventory performed for the detailed time and cost estimate referenced above. Based on a review of tank density in other buildings (Buildings 371, 771, and 776/777), an average tank density of 0.005 tanks per square foot was estimated, and the resultant loading of the wet process area is 99 tanks.

The 43,900 square feet in the building that do not contain processing equipment are assumed to contain offices, locker rooms, and storage areas, which have minimal radiological contamination.

Under the Closure case, all plutonium buildings will undergo DD&D. However, planning of these DD&D activities is in the early stages, and the specific characteristics of each building have not yet been described and quantified. For this reason, the same ratio of wet to glove box processing areas will be used for those buildings that contain both types of processing areas as was used for analysis of the generic building.

Estimation of Resource Requirements. For estimation of resource requirements, it was assumed that tanks will have already been drained and large quantities of SNM will have been removed from the buildings. Subsequent activities that may still contribute dose are deactivation, decontamination, and equipment dismantlement. It is assumed that dose from dismantling of the building itself will not be substantial because most contributors to dose will have been removed.

The time required to dismantle gloveboxes and machining process areas was estimated based on the Site DD&D Program Building 779 Complex Demolition Draft ADS 1030 Parametric Model (EG&G 1995n). Isolation activities identified in this model are equated with deactivation. Removal activities are equated with equipment decontamination and decommissioning. Resource requirements are summarized in Table B-4. Key assumptions that form the basis of this model are as follows:

- Three teams will perform DD&D activities.
- Six workers will compose a team, including two pipefitters, one electrician, one Radiological Control Technician, and two facilitator/remediators.
- Activity durations are based on demonstrations performed with gloveboxes and on similar activities in other areas.
- Time for removal of equipment from offices, lockers, and storage rooms is not considered because no contribution to dose is anticipated.
- Fifty percent of the estimated resource hours would be spent in areas with radiological materials present.

A different set of assumptions was used to estimate person-hours required for DD&D of the wet processing area. The crew would vary by activity but would generally include a Radiological Control Technician, a maintenance worker, and at some times a trucker or laborer. Again, 50% of the estimated resource hours would be spent in areas with radiological materials present.

For the Closure case, staffing requirements were estimated for ten buildings containing the majority of radioactive materials within the clusters of buildings to be decommissioned. These estimates were based on individual building estimates made by Site personnel for planning and costing an accelerated Site cleanup project. Estimates were obtained for deactivation activities and those portions of decontamination activities where contamination is still present and exposure is expected to occur. It was assumed that 50% of the work time would be spent in radiation areas.

ESTIMATION OF DOSE RATES. For the Closure case, deactivation and decontamination were each divided into two phases such that work during the first phase would reduce personnel exposure rates prior to commencement of the second phase. For work performed in the first phase of deactivation, the average dose rate was estimated to be 3 mrem/hr for wet process rooms and 1.5 mrem/hr for other rooms. It was assumed that efforts to reduce the dose rate during the first phase of deactivation would produce a ten-fold decease in the average dose rate for the second phase of deactivation and the first phase of decontamination. The exposure rates used for these two phases were 0.3 mrem/hr for wet process rooms and 0.15 mrem/hr for other rooms. Exposure rates for the final decontamination phase were estimated to be 0.15 mrem/hr for wet process rooms and 0.075 mrem/hr for other process rooms.

Buildings 559, 707, 779, 865, 881, and 883 do not contain wet processing areas so dose rates used for these buildings are as described previously. The remaining buildings (371, 374, 771, 774, 776, and 777) have a mixture of wet and other processing areas. The average dose rate for DD&D of entire buildings with both types of areas would depend on the fractions of wet and other processing areas in each building. The weighting of the wet and other processing areas used to analyze the generic 100,000-square-foot building was assumed to be representative of the average of the buildings with wet processing areas. The weighted average dose rate, or effective dose rate, for the initial phase of deactivation was calculated by dividing the total dose received during deactivation of the 100,000-square-foot building by the person-hours required to do the work. Similarly, the effective dose rate for the second phase of decontamination was calculated by dividing the collective decontamination dose for the 100,000-square-foot building by the person-hours required for that work. The resulting effective dose rate for initial deactivation of buildings with both wet and glove box process areas is 2.3 mrem/hr and the effective dose rate for the final phase of decontamination is 0.1 mrem/hr. The effective dose rate for the second phase of deactivation and initial phase of decontamination is estimated at one tenth of the rate for initial deactivation or 0.2 mrem/hr.

Table B-5 summarizes the collective worker doses estimated for those DD&D activities and shows the annual distribution of the collective doses for each year during which DD&D activities in plutonium-contaminated buildings would be likely to occur. The duration and scheduling of the DD&D activities for each of the buildings were taken from the Closure case. An average annual collective dose was estimated for each building by dividing the total collective dose by the estimated duration of the activities for that building.

B-2.2.3 Dose Estimates for the National Conversion Pilot Project

Under the National Conversion Pilot Project (NCPP), radioactive scrap metal will be used to manufacture products such as containers for radioactive wastes. Prior to manufacturing activities, the NCPP must complete decontamination of Buildings 883 and 865. In preparation for this project, a radiological assessment was performed, which estimated radiological dose to workers, collocated workers, and the public from project activities (MSC 1996). Based on the dose estimates for individual workers for operations such as decontamination, size reduction, ingot production, rolling mill operations, and box fabrication and the assumption that five workers may be used in each operation, collective external dose for annual operations would not exceed 1 person-rem.

Baseline Case: Worker dosimetry for calendar year 1996 measured a collective external dose of 0.832 person-rem. Stack emissions from NCPP occupied buildings (Building 883 and Building 865) are included in the Site emissions used for co-located worker, maximally exposed

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individual, and population doses.

Closure Case: The future of the NCPP is currently uncertain. Operations scenarios include:

- Complete discontinuation of operations, in which case Buildings 883 and 865 would be subject to DD&D
- Continued metallurgical operations utilizing current staff levels
- Additional decontamination activities, in which case Buildings 444 and 447 would be included in the NCPP.

Worker exposure for discontinued operations is expected to drop to zero. Continued metallurgical operations will utilize either radiologically uncontaminated for mildly contaminated feed stock. Worker exposure from these materials will be negligible. Residual contamination remaining in Buildings 883 and 865 will result in worker exposure somewhat less than that received during the decontamination activities performed during the Baseline case. A worker exposure of 6 mrem per year is expected for a total of 32 employees. For the continued metallurgical operations scenario, a total worker dose of 0.192 person-rem per year would be expected during the period of the Closure case. If additional decontamination occurs, worker dose from this activity would be comparable with that previously received by NCPP workers. If additional decontamination is authorized, both this activity and metallurgical operations will occur simultaneously. Thus the combined worker dose for the NCPP will be 0.832 + 0.192 = 1.02 person-rem per year. This is the value used for the Closure case period in this analysis.

B-2.2.4 Dose Estimates for Indirect Activities Related to SNM and Residue Actions

Baseline Case: SNM and Residue activities continue to occur throughout the Baseline case period. Worker dose from these activities are included in the routine ongoing operations dose presented in the next section.

Closure Case: The Closure case provides for much more SNM and Residue activities, requiring separate analysis. Dose to direct workers is estimated through a scale-up process presented in the next section, while indirect worker dose is accounted for at indicated below. Worker dose estimates were developed for use in three SNM and Residue related environmental assessments. These estimates bound the worker dose for each project. During the Baseline case, a portion of each of these projects occurred. These projects are included in Baseline case dose measured by worker dosimetry, plant emissions measured by effluent monitors, and air concentrations measured by ambient air monitoring programs. These environmental assessments are useful in assessing the future impacts of these SNM and Residue related activities.

The *Environmental Assessment for Resumption of Thermal Stabilization of Plutonium Oxide in Building 707* (DOE 1994p) included a detailed approach for well-defined processes and material-handling operations. In contrast, the other two environmental assessments, *Environmental Assessment for Actinide Solution Processing at the Rocky Flats Environmental Technology Site* (DOE 1995k) and *Environmental Assessment for the Consolidation and Interim Storage of Special Nuclear Material at Rocky Flats Environmental Technology Site* (DOE 1995l), used previously developed data that were representative of the processes that would be performed but did not account for all processes and material handling activities. According to a representative from the Radiological Engineering Department at the Site, both studies were based on existing analyses only, which limited their completeness. Additionally, the processes considered in these environmental assessments, especially those for actinide solution stabilization were not as well defined as for thermal stabilization.

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Table B-5. Estimation of Dose from DD&D Activities Under Closure Case

			(Person-rem)																		
Building Cluster	person-rem	DD&D Duration (year)[1]	FY97	FY98	FY99	FY00	FY01	FY02	FY03	FY04	FY05	FY06	FY07	FY08	FY09	FY10	FY11	FY12	FY13	FY14	FY15
B371 Cluster	71.3	4								2.3	2.3		16.6	16.6	16.6	16.6	0.1	0.1	0.1		0.1
B707/750 Cluster	39.0	5									2.5		7.3	7.3	7.3	7.3	0.1	0.1			
B771/774 Cluster	81.1	4	2.6	2.6						18.9	18.9	18.9	18.9	0.1	0.1	0.1	0.1				
Misc Prod Zone	7.8	6										1.3	1.3	1.3	1.3	1.3	1.3	0.1			
B776/777 Cluster	131.9	5				4.2	4.2					24.7	24.7	24.7	24.7	24.7	0.1				
B779 Cluster	17.0	4	5.0	4.0	4.0	4.0	0.1														
B881 Cluster	25.2	3										8.4	8.4	8.4	0.1						
B886 Cluster	13.9	4	4.1	3.2	3.2	3.2	0.1														
B991 Cluster	4.2	2											2.1	2.1							
B779 Cluster	17.0	4	5.0	4.0	4.0	4.0	0.1														
Misc Prod Zone	7.8	6										1.3	1.3	1.3	1.3	1.3	1.3	0.1			
TRU Cluster	0.3	1																	0.1	0.1	0.1
Industrial Zone	3.3	2										1.6	1.6						0.1	0.1	
Buffer Zone	0.2	6								0.01	0.01	0.01							0.01	0.01	0.1
Total DD&D	306.5		11.8	9.8	7.2	11.4	4.4	0	2.5	21.2	21.2	60.8	80.8	60.5	50.0	49.9	1.6	1.4	0.4	0.2	0.2

[1]Includes dose from holdup deactivation and IHSS remediation, but years shown represent D&D only.

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Examination of **thermal stabilization** showed that material handling activities involve substantial support (indirect) functions and associated doses, and processing activities (e.g., brushing of plutonium metal) do not typically involve support functions where exposure occurs. The average ratio of indirect to direct dose for material handling functions is 2. Therefore, a conservative factor of 3 is applied to all doses estimated for direct workers in material handling activities.

With respect to **SNM consolidation**, it is appropriate to apply this factor to the estimated dose in the environmental assessment because the estimated dose represents movement of material into the Room 3331 vault. It is not believed that the estimated dose represents all activities, even after applying this ratio, because processing and repackaging were not included. However, the modified estimate will be more representative than what is published in the environmental assessment. The modified collective dose estimate is 18 rem/year for the seven-year life of the project.

With respect to **actinide solution stabilization**, doses were based specific processes in Buildings 371 and 771. They do not encompass any of the material movement that will be required and do not necessarily account for the total volume of material to be processed. Because the factor discussed above applies to material movement activities, it is not applicable to the estimated dose from this environmental assessment. Therefore, this dose will not be modified, and the caveat must be stated that the anticipated dose for actinide solution stabilization is not fully represented.

B-2.2.5 Dose Scaling Factors for Routine Ongoing Operations

It is necessary to determine the increased worker dose as environmental restoration activities, DD&D activities, and SNM and Residue related activities increase at the Site. The methodology used for scaling Baseline Case year worker doses for these activities is described in the Chapter 5 discussion. The purpose of this section of the appendix is to explain in more detail the results of the organizational interview process that was used to scale each organization's Baseline Case year dose. Table B-6 presents a summary of the data that were collected for the time period 1996 through 2006, including a listing of each organization, the Baseline Case year dose, a rationale for the development of the scaling factors, the scaling factors for the Closure case, and the resultant dose estimates. This table also includes the dose estimates for additional activities that were developed using the methodologies described in the preceding sections.

B-2.2.6 Dose Estimates for Solid Residue Stabilization

During the Baseline case there was no treatment of solid residues beyond installation of carbon vent filters on drums of solid residues not currently vented. Some characterization of residues involving opening of drums, thermal stabilization, and laboratory analysis did occur in Baseline case.

Stabilization of solid residues as described in the *Environmental Assessment, Finding of No Significant Impact, and Response to Comments: Solid Residue Treatment, Repackaging and Storage* (**DOE 1996__?**) will occur as part of the Closure case. Table B-7 summarizes the calculation of estimated collective doses for each type of residue processing.

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Table B-6. Annual Dose Data for Worker Health Impact Assessment

Organization	Org. #	# of TLDs	1994 Dose (person-rem)	Potential Process Impacts: Baseline Case	Potential Process Impacts: Closure Case	Dose Scaling Factors*: Baseline Case Period	Dose Scaling Factors*: Closure Case	Resultant Dose (person-rem): Baseline Case Period	Resultant Dose (person-rem): Closure Case
Dose for organizations whose primary activities will be SNM and Residue related activities.									
Plutonium Operations	58000	33	5.149	Limited brushing of Pu metal continue in Baseline Case year.	Baseline Case dose is estimated to remain constant. Additional dose from interim actions is quantified in the EAs.	1	1	5.149	5.149
Technical Development: 2/3 of the group supports SNM and are considered here	13200	92	4.234	Assume that 2/3 of this group supports SNM activities. For this portion, Baseline Case dose is estimated to remain constant. Additional dose from interim actions is quantified in the EAs.	Assume that 2/3 of this group supports SNM activities. For this portion, Baseline Case dose is estimated to remain constant. Additional dose from interim actions is quantified in the EAs.	1	1	4.234	4.234
Buildings 371/771 Laboratory	82600	21	3.121	Activities expected to remain at 1994 levels.	Increases expected in response to EAs. Dosimetry data from 1984-86 was used to make estimates.	1	1.4	3.121	4.369
Dose for organizations whose doses are expected to drop substantially upon completion of SNM and Residue related activities.									
Buildings 771/774 Operations	13500	84	8.592	Dose due 25% to actinide solutions, 50% to SNM stored in building, 15% to residues, and 10% to building contamination.	Dose due 25% to actinide solutions, 50% to SNM stored in building, 15% to residues, and 10% to building contamination. Dose will be lowered substantially by completion of SNM and Residue related actions.	1	1	8.592	8.592
Building 371 Operations	32000	89	6.900	Operations continue as in 1994.	This organization will continue to participate in SNM consolidation, and associated doses should be included in the EA. Baseline Case dose will increase after consolidation is complete because of the additional amounts of material present in the building.	1	1	6.900	6.900
Safeguards and Security: This portion of group (65%) deals mainly with SNM.	63100	51	6.377	Perform SNM inventories. This group is in charge of all Pu security, including daily checks and moves.	Perform SNM inventories. This group is in charge of all Pu security, including daily checks and moves.	1	1	6.377	6.377
Building 559 Laboratory	82800 82900	34	2.440	Operations continue as in 1994.	Increases from SNM and Residue related actions and waste shipments to WIPP.	1	1.4	2.440	3.416
Dose for organizations whose work is relatively independent of SNM and Residue related activities.									
Radiological Control	61000	559	39.720	Operations and exposures similar to Baseline Case year.	Baseline Case exposure constant. Additional dose from ER and DD&D is calculated separately. Other increases included in EA data.	1	1	39.720	39.720
Fire/Security and Support Maintenance	9100	493	27.530	Based on maintenance personnel levels obtained in socioeconomic analysis.*	Based on maintenance personnel levels obtained in socioeconomic analysis.*	0.73	1.1	20.097	30.283
Wackenhut Security	320		14.959	Activities are expected to remain constant.	Activities are expected to remain constant.	1	1	14.959	14.959
Assay and Storage	22300	72	12.189	Movement of waste and materials be similar to 1994.	Staging of waste for shipment would result in less dose than ongoing storage. SNM consolidation-related doses would still occur.	1	1.8	12.2	21.940
JA Jones Construction	3893		6.310	Tracks with construction management group (org. #60210).	Tracks with construction management group (org. #60210).	1	1.5	6.310	9.465

Solid Waste Processing	22100	48	6.092	Continue operations as in 1994.	Increased waste volumes results in increased treatment and repackaging requirements.	1	1.6	6.1	9.747
Central Engineering	64000	208	6.081	Roughly the same as Baseline Case but might vary with staffing levels of "crafts."	Based on staffing level of "crafts," would increase from DD&D. After DD&D of 1 Pu building, would expect 10% decrease.	1	1.3	6.081	7.905
Metrology	95000	75	4.790	Operations continue as in 1994.	Tracks with NDA, laboratory activity, and tank inspection, with some increase with off-site shipment.	1	1.1	4.790	5.269
Liquid Waste Processing	13100	74	4.588	No strong correlation between dose and throughput. Dose expected to be constant.	No strong correlation between dose and throughput. Dose expected to be constant.	1	1	4.588	4.588
Building 881 Laboratory and Other	82000	107	4.431	This laboratory is nearly at capacity. Large additional quantities would be sent to an off-site laboratory.	This laboratory is nearly at capacity. Large additional quantities would be sent to an off-site laboratory.	1	1	4.431	4.431
Utility Operations	96000	113	3.701	Continued at 1994 levels. This is a low dose job and much of measured dose may be due to workers being "bumped" into the organization and bringing their accumulated dose for the year with them.	Continued at 1994 levels. This is a low dose job and much of measured dose may be due to workers being "bumped" into the organization and bringing their accumulated dose for the year with them.	1	1	3.701	3.701
Safeguards and Security: This portion of group (35%) works with waste, won't be affected by EAs.	63100	28	3.434	35% of dose related to responsibilities for security of SNM-bearing waste.	35% of dose related to responsibilities for security of SNM-bearing waste. Will not change substantially across *CID* cases or with consolidation.	1	1	3.434	3.434
Logistics and Property Management	94000	109	3.183	Mainly due to on-site trucking as described in transportation analysis.	Mainly due to on-site trucking as described in transportation analysis.	***	***	1.620	4.150
Technical Development: 1/3 of group supports waste treatment and DD&D development and is considered here.	13200	46	2.086	Continued level of effort as in 1994.	A portion of this group would be affected by increased DD&D and CTMP projects. DD&D projects are accounted for in DD&D dose.	1	1.5	2.1	3.128
DOE	381		1.857	Same as Baseline Case.	Additional activities would result in additional observation and associated dose.	1	1.25	1.857	2.321
Waste Storage and Disposal/Building 664	21300	44	1.628	B664 Operations include storage, RTR, shipping. Exposure would remain fairly constant given constant shipping volumes to NTS and commercial site. TRU waste is stored in route in the RTR, and RTR is done as part of shipping procedure.	Assume that RTR activities would ramp up to certify waste for on-site disposal. Increased RTR would result in increased dose. Scaling factor is based on comparison of average annual LL disposal rate to the Closure case rate.	1	3.6	1.628	5.861
Waste Storage and Disposal/Waste Repackaging	21400	56	1.595	This group manages waste storage in the tents and is about to complete sludge repackaging operation for ER sludge and saltcrete. Dose will drop upon completion of this task.	This group manages waste storage in the tents and is about to complete sludge repackaging operation for ER sludge and saltcrete. Dose will drop upon completion of this task.	0.6	0.6	0.957	0.957
Nuclear Safety	66000	37	1.580	This organization spends little time in the areas, but dose is not expected to change.	This organization spends little time in the areas, but dose is not expected to change.	1	1	1.580	1.580

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Construction Management	60210	86	1.178	Perform large construction projects similar to Baseline Case year.	Will perform more renovations and support CTMP projects, increasing dose.	1	1.5	1.178	1.767
Safeguards and Security (Other)	63000	141	1.459	These groups receive minimal dose which will stay relatively constant.	These groups receive minimal dose which will stay relatively constant.	1	1	1.459	1.459
Criticality Safety	65000	24	1.176	As long as Pu/SNM are on-site this group's workload is expected to be stable without substantial change in dose.	As long as Pu/SNM are on-site this group's workload is expected to be stable without substantial change in dose.	1	1	1.176	1.176
Occupational Medicine	92000	28	1.073	Source of dose was not readily identified but dose is expected to be constant across the *CID* cases.	Source of dose was not readily identified but dose is expected to be constant across the *CID* cases.	1	1	1.073	1.073
Total Among Interviewed Groups		**2952**	**187.452**					**180**	**220**
Total LCF Among Interviewed Groups								**7E-02**	**9E-02**
Remainder of Plant Dose**			27785			0.79	1.15	22	32
LCF for Remainder of Plant Dose								9E-03	1E-02

* Employment data collected for Chapter 5 discussion on "Socioeconomics"
** Based on overall plant population total.

Table B-7. Estimated Worker Dose from the Residue Stabilization Project

Task	FTE			Timeframe			FTEs in Range	Dose (person-mrem)		
	Per shift	No. shift	Total	Start	End	Duration (Year)		Estimated Annual	Total Annual	Total Project
Salt Processing	35	5	175	Apr-97	May-02	5	50 50 75	1,000 500 300	50,000 25,000 22,500 **97,500**	250,000 125,000 112,500 **487,500**
Ash Processing	20	3	60	Apr-97	May-02	5	30 30	1,000 500	30,000 15,000 **45,000**	150,000 75,000 **225,000**
Repack	6	3	18	Apr-97	May-02	5	18	750	13,500 **13,500**	67,500 **67,500**
Classified Shapes	5	1	5	Apr-97	May-02	5	5	750	3,750 **3,750**	18,750 **18,750**
Wet/ Miscellaneous/ Combination	35	3	105	Apr-97	May-02	3	50 55	1,000 300	50,000 16,500 **66,500**	150,000 49,500 **199,500**
Total									**226,250**	**998,250**

B-2.2.7 Dose Estimate for Packaging of Highly Enriched Uranyl Nitrate for Shipment

Highly enriched uranyl nitrate solutions were shipped off-site during the Baseline case. The highly enriched uranyl nitrate was repackaged into 10-liter shipping containers. Site personnel have estimated the collective doses involved with such repackaging (Kaiser-Hill Baseline case). The repackaging project was broken down into individual tasks and estimates of the collective dose made from the person-hours necessary to accomplish each task and the estimated average dose rate to be experienced by the workers involved. The collective doses for each task were summed for a total estimated collective dose of 3.813 person-rem.

B-2.3 Routine Radiological Emissions and Air Quality Impacts

This section provides air quality discussions and impact assessments from routine radiological emissions to support summaries presented in Sections 4.5 "Air," 4.8.2 "Radiological Health and Safety–Public," and 5.8.2 "Radiological Impacts on Public Health and Safety."

Both actual and calculated air emissions were used to predict contaminant concentrations at receptor locations and for comparison with applicable air quality regulations. The area of concern is a 50-mile (80-kilometer) radius from the center of the Site. Contaminant concentrations were assessed at selected receptor locations within this area.

The approach used to assess potential air quality impacts consisted of a review of available radiological and nonradiological emissions data to identify the contaminants of concern. Identification of a contaminant of concern may be influenced by the potential quantity and type of the emissions, location of the emission source with respect to possible receptors, type of source (point source, area source, or non-point source[1]), hazard (e.g., toxicity, carcinogenicity) associated with the contaminant, compliance with regulations or other established limits on quantities, and frequency of emissions. The screening of the sources was designed to eliminate from detailed analysis those that are not of concern, either as a minor quantity emission or from a minimal ability to impact human health or the environment.

B-2.3.1 Radiological Air Quality Analysis Methodology

The purpose of the radiological analysis was to identify and evaluate the impacts to air quality from RFETS activities. Radiological impacts were evaluated in terms of effective dose equivalent (EDE). EDE was estimated by using conservative source term estimates together with an approved air dispersion modeling code. For purposes of this *CID*, impacts were analyzed for co-located workers, a maximally exposed individual, and a member of the public residing within a 50-mile radius.

Radiological air emissions from the Site occur from both point sources and area sources. Radioactive air emissions are monitored in 17 buildings continuously from 63 locations. Ambient concentrations of radionuclides are also monitored at the Site boundary and in the surrounding communities.

This *CID* analyses must consider airborne radiological materials because they contribute doses to on-site workers and to members of the general public who live off-site. Radiation workers are subject to U.S. Code of Federal Regulations, Title 10, Part 20 (10 CFR 20), *Standards for Protection Against Radiation*, which states that all accumulated doses for a worker will not exceed an Effective Dose Equivalent (EDE) of 5 rem/year. Dose from air emissions to members of the general public are governed directly by 40 CFR 61, Subpart H, *National Emission Standards for Hazardous Air Pollutants* (NESHAP). This regulation requires that calculated dose from emissions shall not exceed an EDE of 10 mrem/year via the air pathway. A computer dispersion model was selected as the method to estimate dose concentrations to members of the general public. Output from the dispersion model also was used to estimate the contribution of the air pathway to the accumulated dose of workers at the Site.

B-2.3.1.1 Dispersion Model Selection Criteria

CAP88-PC, a variation of the Clean Air Act Assessment Package–1988 (CAP88), was chosen as the method for assessing radiological air impacts for this *CID*. Other methods considered were a U.S. Environmental Protection Agency (EPA) approved sampling method or other computer simulation package, such as AIRDOS-PC. CAP88-PC was prepared for DOE by the EPA.

Gaussian plume models, such as CAP88-PC, tend to conservatively predict ambient

[1]A point source is typically a stack or other concentrated source of emissions. An area or non-point source covers a distributed area. Wind blown dust from a construction site is an example of an area source.

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concentrations (Rood 1995). In addition, CAP88-PC is a risk-based pathway model that has been accepted by the EPA and DOE. It is currently used by the Site for air dispersion modeling and dose assessment.

CAP88-PC uses a modified Gaussian plume equation to estimate the average dispersion of radionuclides released from up to six sources. The sources can be either elevated stacks or uniform area sources. Plume rise can be calculated assuming either a momentum or buoyancy-driven plume. Capabilities of CAP88-PC are summarized below:

- Point or area source terms
- Long-term release rates
- Source to receptor distance of 50 miles
- Flat terrain model
- Multiple receptor dose/risk calculations
- Multiple stack/area sources
- Population and maximally exposed individual dose calculations
- Manual plume rise input
- Gaussian diffusion with modifications
- Dry deposition and settling
- Precipitation scavenging
- Short-lived gaseous radionuclides
- Six derived external/ingestion exposure pathways

CAP88-PC produces results that agree with experimental data as well as any other model. The CAP88-PC software package allows users to perform full-featured dose and risk assessments in a personal computer environment for the purpose of demonstrating compliance with 40 CFR 61.93(a) (Parks 1992). Because of the aforementioned advantages, CAP88-PC was selected over either CAP-88 or AIRDOS-PC.

B-2.3.1.2Model Parameters and Assumptions

The dispersion model, CAP88-PC, contains default values for a number of locations, including the Site. The EPA and DOE accept the location-specific default values to demonstrate compliance with 40 CFR 61.93(a). Representative parameters are presented below in Table B-8. The CAP88-PC User's Manual contains a more detailed discussion of model parameters and assumptions (Parks 1992).

Table B-8. Receptor Comparison Table

Parameter	Maximally Exposed Individual	Population	Co-Located Worker
Breathing Rate			
Inhalation rate of man (cm^3/hour)	9.167×10^5	9.167×10^5	9.167×10^5
Human Food Utilization Factors			
Ingestion rate of meat (kg/year)	85	85	85
Ingestion rate of leafy vegetables (kg/year)	18	18	18
Ingestion rate of produce (kg/year)	176	176	176
Ingestion rate of milk (liter/year)	112	112	112
Decontamination Factors			
Fraction of radioactivity retained on leafy vegetables and produce after washing	0.5	0.5	0.5
Animal Feed Consumption Factors			
Contaminated feed/forage (kg/day, dry weight)	15.6	15.6	15.6
Dairy Productivity (L/day)	11	11	11
Meat Animal Slaughter Parameters			
Muscle mass of animal at slaughter (kg)	200	200	200
Fraction of herd slaughtered (per day)	3.81 x 10-3	3.81 x 10-3	3.81 x 10-3
Swimming Parameters			
Fraction of time spent swimming	0.0	0.0	0.0
Depth of water for dilution factor for water immersion doses (cm)	1.0	1.0	1.0

The following urban food source parameters, shown in Table B-9, were changed from the CAP88-PC defaults to Colorado-specific values for an urban food source scenario. These data are also are part of CAP88-PC. Table B-9 presents some of the parameters, such as fractions of vegetables, milk, and meat from the assessment area, which are expected to be conservative (Parks 1992).

Table B-9. Parameters for an Urban Food Source Scenario

	Vegetable	Milk	Meat
Fraction Home Produced	0.076	0	0.008
Fraction from Assessment Area	0.924	1.0	0.992
Fraction Imported	0	0	0
Beef Cattle Density	1.130×10^{-1} number/square km		
Milk Cattle Density	3.500×10^{-1} number/square km		
Land Fraction Cultivated for Vegetable Crops	1.390×10^{-2}		

STACK PARAMETERS. Stack parameters used in this analysis are summarized below in Table B-10.

Table B-10. Input Stack Parameters

Quadrant	Location of Greatest Emission Activity	Stack Height (m)	Stack Diameter (m)	Stack Temperature (C)	Effluent Velocity (m/s)
Northwest (300 and 500 buildings)[1]	374-MAI	12.4	3.10	70	0.1
Northeast (700 and 900 buildings)	771-MAI	44.2	3.05	70	9.01
Southeast (800 buildings)	881-MAI	12.47	2.44	70	5.84
Southwest (400 buildings)	444-MAI	5.12	2.92	70	6.38
Interim Bulk Soil Storage Facility[2]		9.14	0.61	70	6
LTTD Facility[2]		9.14	0.61	70	6
Microwave Solidification Facility[2]		9.14	0.61	70	6

[1]This was considered to be a J stack.
[2]Future point source stack parameters were estimated.

RADIONUCLIDES. Radionuclide default values were used for size and lung clearance class for inhaled particles. The size refers to activity medium aerodynamic diameter for particulates in micrometers (mm). Lung clearance class involves the length of time that the radionuclide particle remains in the lung until it is cleared from the organ. This is a function of the chemical form of the radionuclide, the biological and radioactive half-life. Table B-11 presents size and lung clearance class for radionuclides present in soils at all individual hazardous substances sites.

Table B-11. Radionuclide Size and Lung Clearance Class

Radionuclide	Size (mm)	Lung Clearance Class
Americium-241	1.0	
Plutonium-238	1.0	
Plutonium-239/-240	1.0	
Uranium-233/234	1.0	
Uranium-235	1.0	
Uranium-238	1.0	

B-2.3.1.3Meteorological Parameters

The meteorological data specifically required by CAP88-PC requires the user-specified windfile annual precipitation, annual temperature, and "height of lid" or also termed the "mixing layer."

METHODOLOGY. Because CAP88-PC was used to calculate chronic exposure for the Site over a 10-year period, from 1996 to 2006, meteorological averages over a several-year period would be most representative for this *CID* cases. Five years of wind data were incorporated into the windfile that the code uses for dispersion of the radionuclides. Precipitation, temperature, and mixing height values used in the code were also taken from references that incorporated meteorological data from more than one year. The basis for using several years of meteorological data was to establish a representative year for chronic exposure effects that are predicted by the model.

WINDFILE. Data specific to wind conditions from 1989 through 1993 were incorporated into the model. 1993 was the last year for which data were available at the time the analysis was performed for the Baseline Case. Average wind speed and direction for these years was used in the stability array (STAR) file as CAP88-PC input. This data is shown in Table B-12.

Table B-12. STAR File used for CAP88-PC runs

Wind Direction	Stability Class	1 - 3 knots	4 - 6 knots	7 - 10 knots	11 - 16 knots	17 - 21 knots	> 21 knots
N	A	0.002305	0.003673	0.000000	0.000000	0.000000	0.000000
NNE	A	0.001990	0.006235	0.000000	0.000000	0.000000	0.000000
NE	A	0.002354	0.007709	0.000000	0.000000	0.000000	0.000000
ENE	A	0.002839	0.007589	0.000000	0.000000	0.000000	0.000000
E	A	0.002888	0.009788	0.000000	0.000000	0.000000	0.000000
ESE	A	0.002451	0.010174	0.000000	0.000000	0.000000	0.000000
SE	A	0.002038	0.008314	0.000000	0.000000	0.000000	0.000000
SSE	A	0.001869	0.004278	0.000000	0.000000	0.000000	0.000000
S	A	0.001602	0.002634	0.000000	0.000000	0.000000	0.000000
SSW	A	0.000971	0.001716	0.000000	0.000000	0.000000	0.000000
SW	A	0.001019	0.001619	0.000000	0.000000	0.000000	0.000000
WSW	A	0.000777	0.001329	0.000000	0.000000	0.000000	0.000000
W	A	0.001043	0.001547	0.000000	0.000000	0.000000	0.000000
WNW	A	0.000946	0.001813	0.000000	0.000000	0.000000	0.000000
NW	A	0.001141	0.002272	0.000000	0.000000	0.000000	0.000000
NNW	A	0.001432	0.002562	0.000000	0.000000	0.000000	0.000000
N	B	0.000437	0.006767	0.000000	0.000000	0.000000	0.000000
NNE	B	0.000510	0.008749	0.000000	0.000000	0.000000	0.000000
NE	B	0.000510	0.009546	0.000000	0.000000	0.000000	0.000000
ENE	B	0.000218	0.006670	0.000000	0.000000	0.000000	0.000000
E	B	0.000340	0.008410	0.000000	0.000000	0.000000	0.000000
ESE	B	0.000267	0.011721	0.000000	0.000000	0.000000	0.000000
SE	B	0.000218	0.012422	0.000000	0.000000	0.000000	0.000000
SSE	B	0.000194	0.006743	0.000000	0.000000	0.000000	0.000000
S	B	0.000218	0.002803	0.000000	0.000000	0.000000	0.000000
SSW	B	0.000121	0.002078	0.000000	0.000000	0.000000	0.000000
SW	B	0.000097	0.001740	0.000000	0.000000	0.000000	0.000000
WSW	B	0.000097	0.001643	0.000000	0.000000	0.000000	0.000000
W	B	0.000315	0.001595	0.000000	0.000000	0.000000	0.000000
WNW	B	0.000170	0.001861	0.000000	0.000000	0.000000	0.000000
NW	B	0.000315	0.002127	0.000000	0.000000	0.000000	0.000000
NNW	B	0.000413	0.003770	0.000000	0.000000	0.000000	0.000000
N	C	0.000315	0.004640	0.009570	0.000000	0.000000	0.000000
NNE	C	0.000510	0.003867	0.007468	0.000000	0.000000	0.000000
NE	C	0.000364	0.003142	0.004543	0.000000	0.000000	0.000000

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ENE	C	0.000315	0.001643	0.001982	0.000000	0.000000	0.000000
E	C	0.000291	0.002151	0.001740	0.000000	0.000000	0.000000
ESE	C	0.000049	0.003287	0.004036	0.000000	0.000000	0.000000
SE	C	0.000097	0.004326	0.007975	0.000000	0.000000	0.000000
SSE	C	0.000170	0.004447	0.005365	0.000000	0.000000	0.000000
S	C	0.000170	0.002513	0.001885	0.000000	0.000000	0.000000
SSW	C	0.000146	0.001474	0.001788	0.000000	0.000000	0.000000
SW	C	0.000194	0.000846	0.002054	0.000000	0.000000	0.000000
WSW	C	0.000121	0.000580	0.002513	0.000000	0.000000	0.000000
W	C	0.000243	0.001281	0.004084	0.000000	0.000000	0.000000
WNW	C	0.000291	0.001184	0.004833	0.000000	0.000000	0.000000
NW	C	0.000364	0.001450	0.005317	0.000000	0.000000	0.000000
NNW	C	0.000218	0.002755	0.005099	0.000000	0.000000	0.000000
N	D	0.000995	0.011552	0.014887	0.009957	0.001088	0.000314
NNE	D	0.000704	0.007492	0.007540	0.004616	0.000314	0.000000
NE	D	0.000704	0.005849	0.003698	0.001643	0.000145	0.000000
ENE	D	0.000752	0.004157	0.001619	0.000387	0.000000	0.000000
E	D	0.000437	0.003456	0.001233	0.000169	0.000000	0.000000
ESE	D	0.000097	0.002683	0.001571	0.000580	0.000024	0.000000
SE	D	0.000267	0.004471	0.004616	0.001402	0.000121	0.000048
SSE	D	0.000315	0.007782	0.008821	0.003794	0.000338	0.000121
S	D	0.000607	0.010658	0.010561	0.002731	0.000266	0.000073
SSW	D	0.000461	0.010755	0.009619	0.002441	0.000314	0.000048
SW	D	0.000752	0.010972	0.013485	0.003214	0.000435	0.000048
WSW	D	0.000679	0.011165	0.014766	0.008700	0.002272	0.000411
W	D	0.000704	0.015346	0.011214	0.016748	0.008507	0.007081
WNW	D	0.000704	0.014621	0.013534	0.030572	0.016627	0.011987
NW	D	0.000607	0.014549	0.012833	0.015250	0.005099	0.001426
NNW	D	0.000752	0.013147	0.016096	0.007879	0.000967	0.000145
N	E	0.000728	0.004640	0.001233	0.000000	0.000000	0.000000
NNE	E	0.000510	0.002441	0.000846	0.000000	0.000000	0.000000
NE	E	0.000364	0.001643	0.000411	0.000000	0.000000	0.000000
ENE	E	0.000340	0.001305	0.000145	0.000000	0.000000	0.000000
E	E	0.000243	0.001523	0.000024	0.000000	0.000000	0.000000
ESE	E	0.000170	0.001160	0.000073	0.000000	0.000000	0.000000
SE	E	0.000267	0.002078	0.000338	0.000000	0.000000	0.000000
SSE	E	0.000437	0.003480	0.000943	0.000000	0.000000	0.000000
S	E	0.000485	0.006163	0.002683	0.000000	0.000000	0.000000
SSW	E	0.000340	0.006042	0.002368	0.000000	0.000000	0.000000

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SW	E	0.000437	0.010537	0.005293	0.000000	0.000000	0.000000
WSW	E	0.000704	0.011963	0.007854	0.000000	0.000000	0.000000
W	E	0.000874	0.010706	0.001498	0.000000	0.000000	0.000000
WNW	E	0.000849	0.009788	0.001257	0.000000	0.000000	0.000000
NW	E	0.000946	0.009401	0.004036	0.000000	0.000000	0.000000
NNW	E	0.000704	0.007057	0.004423	0.000000	0.000000	0.000000
N	F	0.001626	0.002900	0.000000	0.000000	0.000000	0.000000
NNE	F	0.001383	0.001788	0.000000	0.000000	0.000000	0.000000
NE	F	0.001383	0.001619	0.000000	0.000000	0.000000	0.000000
ENE	F	0.001383	0.001088	0.000000	0.000000	0.000000	0.000000
E	F	0.000946	0.001885	0.000000	0.000000	0.000000	0.000000
ESE	F	0.001043	0.002006	0.000000	0.000000	0.000000	0.000000
SE	F	0.001189	0.002151	0.000000	0.000000	0.000000	0.000000
SSE	F	0.001262	0.002562	0.000000	0.000000	0.000000	0.000000
S	F	0.001529	0.004060	0.000000	0.000000	0.000000	0.000000
SSW	F	0.001844	0.003698	0.000000	0.000000	0.000000	0.000000
SW	F	0.002014	0.005969	0.000000	0.000000	0.000000	0.000000
WSW	F	0.002839	0.005317	0.000000	0.000000	0.000000	0.000000
W	F	0.002378	0.007033	0.000000	0.000000	0.000000	0.000000
WNW	F	0.002791	0.006308	0.000000	0.000000	0.000000	0.000000
NW	F	0.002839	0.006598	0.000000	0.000000	0.000000	0.000000
NNW	F	0.002014	0.004519	0.000000	0.000000	0.000000	0.000000

ANNUAL PRECIPITATION. The value used for precipitation for input for all files was from the *Rocky Flats Environmental Technology Site Historical Data Summary* (AeroVironment 1995), which is a compilation of data from 1964 through 1977 and 1984 through 1993. (No data are available for 1978 through 1983.) The annual average precipitation was 14.3 inches or 36.3 centimeters.

The quantity of airborne particulate matter that will be washed out of the atmosphere is proportional to the quantity of precipitation. Several years of data provide a representative average of precipitation at the Site.

ANNUAL AMBIENT TEMPERATURE. The value used for temperature input to CAP88-PC files was from the *Rocky Flats Environmental Technology Site Historical Data Summary* (AeroVironment 1995). The annual average temperature was 49.5° Fahrenheit (F) or 10° Celsius (C). Temperature is a parameter used to assist in predicting buoyancy and dispersion rates in a dispersion model.

HEIGHT OF LID. The mixing lid is the height of the atmosphere where atmospheric conditions exist that provide a barrier so that terrestrial originating emissions cannot pass and enter heights further above the ground. Terrestrial events, for instance, a radioactive plume, can affect only the layer of atmosphere below the "mixing lid," a factor in the dispersion and diffusion of the plume.

The value that was used as input into CAP88-PC was 1405 meters. This value is the mean value of the annual average morning mixing height of 268 meters and the afternoon mixing height of 2543 meters for the Denver area (EPA 1972). This value was also used in the 1993 *Radionuclide Air Emissions Annual Report* (DOE 1994i).

Dispersion Parameters. Table B-13 presents default dispersion parameters in CAP88-PC which were used in the analyses (Parks 1992).

Table B-13. Default Dispersion Parameters in CAP88-PC

Buildup Times	
For activity in soil (years)	$1.00 \times 10^{+2}$
For radionuclides deposited on ground/water (days)	$3.65 \times 10^{+4}$
Weathering	
Removal rate constant for physical loss (per hour)	2.90×10^{-3}
Fallout Interception Fractions	
Vegetables	2.00×10^{-1}
Pasture	5.70×10^{-1}

B-2.3.1.4Population Distributions

The population file used for the Baseline Case and this *CID* cases is the same one used for the 1993 *Radionuclide Air Emissions Annual Report* (DOE 1994i). Because populations are dynamic, the projected population for this *CID* cases activities that would occur in the future were taken from the *1994 Population, Economic, and Land Use Data Base for Rocky Flats Environmental Technology Site* for the year 2005 (DOE 1995e). The projected populations for the years 2005 and 2015 were given for 1.6- to 80-kilometer (1 to 50 miles) distances for 16 sectors from the Site. The year 2006 data were linearly interpolated from data for years 2005 and 2015. The populations for the ten distances used in the population file from the center of the Site to 50 miles are listed in Table B-14.

Table B-14. Populations Used for Baseline Case and Projected Year Population Dose Assessments

Distance from the Site (miles)	Baseline Case Population Year 1993	Projected Population Year 2006
1.0	0	0
2.0	0	0
3.0	72	2,090
4.0	790	7,173
5.0	8,880	18,262
10	330,573	359,146
20	870,689	928,280
30	685,943	831,041
40	119,811	217,021
50	201,597	306,040
Total	**2,218,355**	**2,669,053**

B-2.3.1.5Receptor Description

Compliance with the U.S. Environmental Protection Agency, July 1990, *National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities* (EPA 1990a) requires "calculating the highest effective dose equivalent to any member of the public at any off-site point where there is a residence, school, business or office." The highest effective dose to any member of the public is referred to as the maximally exposed individual. For

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the purposes of this *CID*, the maximally exposed individual is assumed to be located along the eastern boundary of the Site.

A geographic information system (GIS) was used to determine dose. GIS was used as a tool for the capture, storage, manipulation, retrieval, and display of data collected for this *CID* radiological air quality impacts assessment. GIS products included maps, tables, and data summaries. The dose at any location can be readily determined with this technique.

B-2.3.2 Impacts from Baseline and Closure Cases Radiological Emissions

Radiological air emissions originate from both point sources (such as stacks) and area sources, such as fugitive dust generated during soil excavation which is a part of environmental restoration. Not all environmental restoration activities are expected to generate detectable quantities of fugitive dust that would contain radionuclides, (e.g., placing the cap over Operable Unit 4 (OU4)).

Radiological pollutants have been monitored at the Site for several years. Results of air monitoring activities are published in annual reports such as the 1993 *Radionuclide Air Emissions Annual Report* (DOE 1994I). These documents provide input for estimating radiological source terms. The general assumptions used to estimate radiological emissions under Baseline Case and this *CID* cases are described below.

BASELINE CASE. Data from the 1993 Radionuclide Air Emissions Annual Report (DOE 1994I) were used to develop the Baseline Case radioactive air emissions at the Site. For point sources, a scaling factor was applied to the 1993 emissions data to reflect work force reductions, limited waste management and special nuclear management operations. For area sources, the estimated 1993 radionuclide air emissions resulting from the resuspension of past radioactive soil contamination were used for Baseline Case conditions at the site. The resuspension processes are discussed in detail in a report titled *Resuspension of Soil Particles from Rocky Flats Containing Plutonium Particulate* (Langer, 1991). Annual quantities of radioactive materials from point and area sources for Baseline Case conditions are listed in Table B-15.

Table B-15. Summary of Radionuclide Air Emissions – Baseline Case Period

	Plutonium -238	Plutonium -239/-240	Americium -241	Uranium -233/-234	Uranium -235	Uranium -238	Hydrogen-3 (Tritium)
Source Type	(Ci/yr)	(Ci/yr)	(Ci/yr)	(Ci/yr)	(Ci/yr)	(Ci/yr)	(Ci/yr)
Area Sources							
Soil Resuspension	–	3.40×10^{-5}	5.70×10^{-6}	1.10×10^{-6}	2.20×10^{-7}	3.00×10^{-8}	–
Point Sources							
Site Operations	1.49×10^{-8}	1.20×10^{-6}	2.04×10^{-7}	8.31×10^{-7}	3.80×10^{-12}	1.08×10^{-6}	4.97×10^{-3}

CLOSURE CASE. Data from the 1993 Radionuclide Air Emissions Annual Report (DOE 1994) were also used to develop the radioactive air emissions for the Closure Case. For point sources related to continued Site operations, a scaling factor was applied to the 1993 emissions data to reflect increased waste handling and treatment operations. For specific activities such as the treatment of environmental restoration waste, SNM consolidation, residue treatment, and deactivation, decontamination, and decommissioning (DD&D) separate emission evaluations were performed. Area source emission estimates from proposed environmental restoration operations were calculated using emission factors obtained from Compilation of Air Pollutant Emission Factors, a U.S. Environmental Protection Agency document commonly referred to as AP-42 (EPA 1995a). These emission factors, combined with the maximum radionuclide concentrations in a specific source area, were used to estimate radiological emissions during excavation. Standard dust control measures such as watering and stabilization were assumed during excavation to reduce

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Table B-16. Summary of Environmental Restoration Air Emissions–draft Site Closure Plan

Source Type	Area	Plutonium-238 (Ci/yr)	Plutonium-239/-240 (Ci/yr)	Americium-241 (Ci/yr)	Uranium-233/-234 (Ci/yr)	Uranium-235 (Ci/yr)	Uranium-238 (Ci/yr)	Hydrogen-3 (Tritium) (Ci/yr)
Area Sources								
Environmental Restoration	OU2		1.63×10^{-4}	2.36×10^{-6}	2.83×10^{-6}	1.70×10^{-7}	1.67×10^{-6}	
	OU5		4.77×10^{-8}	6.86×10^{-9}	4.18×10^{-5}	9.99×10^{-6}	5.67×10^{-4}	
Point Sources								
Site Operations		1.33×10^{-7}	5.22×10^{-3}	1.85×10^{-6}	2.15×10^{-5}	2.34×10^{-8}	2.65×10^{-5}	1.03×10^{-1}
DD&D		8.20×10^{-7}	1.21×10^{-5}	3.96×10^{-6}	4.12×10^{-6}		1.60×10^{-5}	1.91×10^{-1}
LTTD Facility[1]	OU2 Soil		5.53×10^{-7}	8.05×10^{-9}	9.64×10^{-9}	1.90×10^{-9}	5.83×10^{-8}	
	OU5 Soil		1.62×10^{-10}	2.34×10^{-11}	1.42×10^{-7}	3.40×10^{-8}	1.93×10^{-6}	

[1]Low Temperature Thermal Desorption.

emissions of fugitive dust. Specific details concerning the emission factors and assumptions used for the point source and area source radioactive air quality impacts analysis are contained in the Draft SWEIS Air Quality Technical Support Document. Radiological air emissions from area and point sources for the Closure Case are summarized in Table B-16.

Estimated doses resulting from the Baseline Case period and the Closure Case, together with associated standards, are presented below in Table B-17.

Table B-17. Dose Estimates for Baseline and Closure Cases

Receptors	Baseline Case (mrem)	Closure Case	Standard (mrem)
Co-located Worker	0.29	5.3 mrem	5,000[1]
Maximally Exposed Individual	0.0052	0.23 mrem	10^2
Population (person-rem)[3]	0.270	22.9 per-rem	–

[1]The radiological dose standard presented is total dose from all exposure pathways.
[2]Only for the air pathway.
[3]Effective dose equivalent projected for the population within 50 miles of the Site. The dose to an average individual within this area is the stated dose divided by the projected population of 2,660,217 people for the year 2006.

The airborne radiological doses are presented in Tables B-18 and B-19 for the Baseline and Closure Cases, respectively. These tables include columns for the source description, source ID, maximally exposed individual, and co-located worker. The purpose of a source ID column was to provide an abbreviated method of identifying sources, particularly for plotting doses on Figures B-1 and B-2. The bottom row of the tables contains the maximum received dose. The maximum received dose is not the sum of doses from all sources for the Baseline and Closure Cases. Specifically, the receptor with the greatest dose does not necessarily coincide with the maximally exposed receptor from each source, because source maximums typically occur at different geographical locations. Therefore the contributing doses from all the sources cannot be directly added to obtain the maximum received dose.

Figures B-1 and B-2 depicts dose in millirem for the maximally exposed individual and co-located worker, according to source ID. The vertical axes of the figures is a logarithmic scale of dose, and a bar or ribbon is provided for both the co-located worker and the maximally exposed individual.

As illustrated on the figures, the contribution for a particular source is often proportional for both co-located worker and maximally exposed individual. For example, plutonium-239 is the major contributor to both co-located worker and maximally exposed individual for the Baseline Case period, as depicted on Figure B-1. Plutonium-239 in this instance originates from soil resuspension, an area source.

Table B-18. Contributions to Dose (EDE) – Baseline Case

Source Description	Source ID	Maximally Exposed Individual (mrem)	Co-Located Worker (mrem)
Point Source Stack in Northeast Quadrant	1pne	2.40×10^{-5}	1.10×10^{-4}
Point Source Stack in Northwest Quadrant	1pnw	2.50×10^{-6}	7.30×10^{-5}
Point Source Stack in Southeast Quadrant	1pse	1.70×10^{-5}	2.10×10^{-4}
Point Source Stack in Southwest Quadrant	1psw	1.90×10^{-6}	1.80×10^{-5}
Area Source–Soil Resuspension: Americium-241 Contributions	Am-241	1.10×10^{-3}	5.00×10^{-2}
Area Source–Soil Resuspension: Plutonium-239/-240 Contributions	Pu-239	4.00×10^{-3}	2.40×10^{-1}
Area Source–Soil Resuspension: Uranium-233/234 Contributions	U-234	5.40×10^{-5}	4.20×10^{-3}
Area Source–Soil Resuspension: Uranium-235 Contributions	U-235	8.50×10^{-6}	6.70×10^{-4}
Area Source–Soil Resuspension: Uranium-238 Contributions	U-238	1.30×10^{-5}	1.60×10^{-4}
Maximum Received Dose for the Baseline Case		5.20×10^{-3}	2.90×10^{-1}

Table B-19. Contributions to Dose (EDE)–Closure Case

Source Description	Source ID	Maximall y Exposed Individua l (mrem)	Co-Located Worker (mrem)
Point Source Stack in Northeast Quadrant	3pne	5.10×10^{-3}	2.40×10^{-2}
Point Source Stack in Northwest Quadrant	3pnw	2.10×10^{-1}	5.30
Point Source Stack in Southeast Quadrant	3pse	9.10×10^{-4}	1.10×10^{-2}
Point Source Stack in Southwest Quadrant	3psw	7.80×10^{-5}	3.00×10^{-3}
Point Source–Environmental Restoration: Low Temperature Thermal Desorption Facility, Contribution from OU2	3pl2	2.20×10^{-5}	9.10×10^{-4}
Point Source–Environmental Restoration: Low Temperature Thermal Desorption Facility, Contribution from OU5	3pl5	2.70×10^{-5}	1.10×10^{-3}
Area Source–Environmental Restoration: OU2	3OU2	1.40×10^{-2}	2.80
Area Source– Environmental Restoration: OU5	3OU5	2.50×10^{-2}	3.80
Maximum Received Dose for Closure Case		2.30×10^{-1}	5.40

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Figure B-1. Contributions to Dose (EDE) – Baseline Case

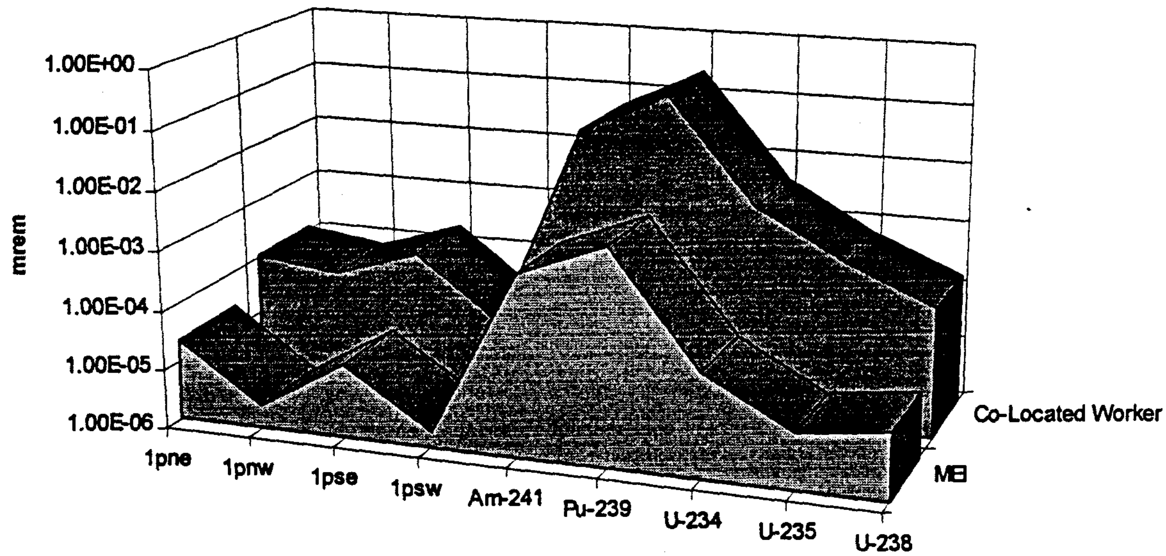

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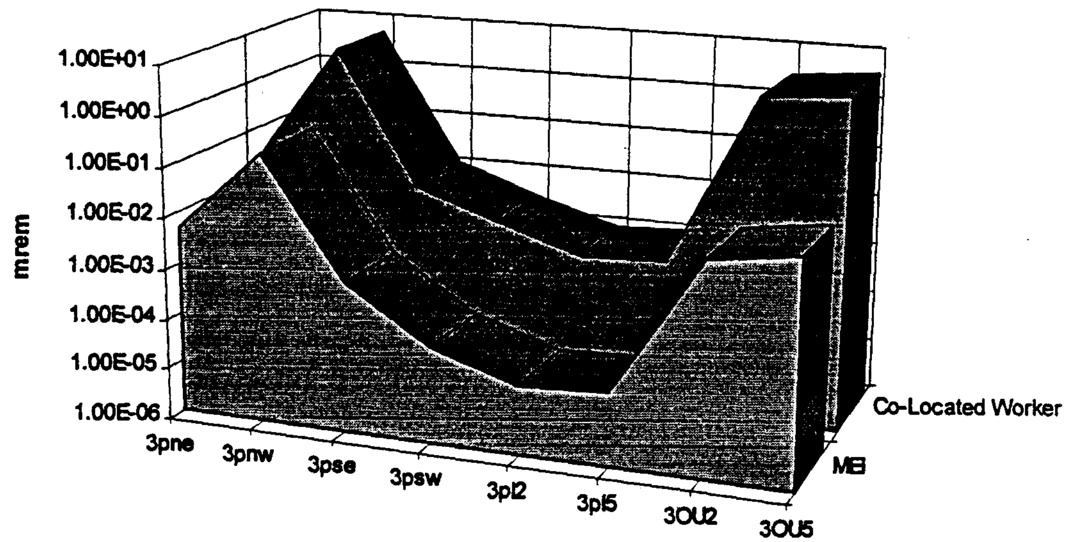
Figure B-2. Contributions to Dose (EDE) - Closure Case



B-2.3.3 Graphical Representation of Doses

A geographic information system was used to graphically illustrate the results of the CAP88-PC runs. The following approach was used in generating the plots.

1. The ASCII files of model results were converted from a polar coordinate format to a Cartesian coordinate format that could be imported into Arc/Info (the GIS software used to produce the plots). A QuickBasic program was written to perform this task. The state plane coordinates of each source for each model run were input. The source origin was used to locate the model results in a geographic reference frame. The model results for each area source and each point source were processed independently.
2. A point coverage was created for each model run. The importing and Arc/Info processing were handled by a series of custom Arc Macro Languages.
3. Each point coverage was converted to a Triangulated Irregular Network format.
4. Each Triangulated Irregular Network was converted into two grids, one "fine" grid with a 100-foot grid cell size and one "coarse" grid with a 1,500-foot grid cell size. Both fine and coarse grids have the same origin and cell size irrespective of radionuclide or source location.
5. All "fine" grids for a given radionuclide were totaled on a cell-by-cell basis. That is, for each cell within each grid, the values representing the dose from each source of a given radionuclide were totaled to produce a grid representing the total dose for that radionuclide from all sources. A similar operation was performed on all "coarse" grids for each radionuclide.
6. The "total dose" grids were contoured for each radionuclide to produce the "fine" and "coarse" resolution contour plots. Example plots using a continuously varying color shade in the background to represent dosages were also provided.
7. A third series of plots was generated that depict the population dose for each radionuclide. These plots were produced only from the coarse grids. A population file was converted to a point coverage. This coverage was converted to a Triangulated Irregular Network and was converted to a "coarse" resolution grid with the same origin and grid cell size as the other coarse grids. The coarse grid representing the individual dose for each radionuclide was multiplied by the population grid on a cell-by-cell basis to produce grids representing the population dose for each radionuclide. Again, these grids were contoured to produce the final plots.
8. A summation of the population dose from all radionuclides was developed. For the Baseline case, this was accomplished by adding the population dose grids for radionuclide. For the *CID* cases, all radionuclides for each source were combined in a single CAP88-PC run. Then the population dose for the Baseline and Closure Cases was calculated by multiplying a source grid by the population grid via the geographic information system. The approach used for the *CID* cases streamlined the data processing. However, the end results are the same regardless of where the data were processed either in CAP88-PC or by the geographic information system.

B-3 Nonradiological Human Health and Safety

The Nonradiological Human Health and Safety section of Appendix J addresses air quality and health effects. Sections B-3.1 through B-3.3 address nonradiological air quality. Section B-3.4 describes the human health impacts assessment methodology and results for both the worker and public for contaminant exposures. These assessments include possible health impacts from air pollutants and exposures due to ingestion of contaminated ground water. Assessment of worker health and safety from occupational exposures is addressed in Appendix N, "Accidents."

B-3.1 Nonradiological Air Quality Analysis Methodology

This section describes the procedures and assumptions used to estimate the air quality impacts from nonradioactive sources of pollutants at the Site. This includes the methodology used to estimate nonradiological air quality emissions under Baseline Case conditions and the Closure Case. In addition, the modeling methodology employed is also described. This section is provided in support of the nonradiological air quality assessments presented in Chapters 4 and 5.

B-3.1.1 Model Selection Criteria

The dispersion modeling analysis performed for the nonradiological air quality analysis consisted of three distinct types: point source, fugitive dust, and complex terrain modeling. The following subsections present the details concerning each modeling type.

POINT SOURCE MODELING. The EPA's Industrial Source Complex Air Quality Dispersion Model (ISC2) was used for air quality dispersion modeling in areas where terrain does not exceed the height of the emission sources as outlined in EPA's *Industrial Source Complex (ISC2) Dispersion Model User's Guide* (EPA 1992a). The ISC2 model is a validated model used to determine air quality impacts from existing, modified, and new sources of air pollutants throughout the United States and is thus considered appropriate for this application. The ISC2 dispersion model's short-term algorithm was used to estimate concentrations of air pollutants for various time periods at ground-level receptors.

The ISC2 model applies a steady-state Gaussian plume equation for a continuous source. The generalized Briggs plume-rise equations were used to calculate plume rise as a function of downwind distance. The rural dispersion algorithm was used, plume rise due to buoyancy-induced dispersion was considered, and the Pasquill-Gifford curves were used to calculate lateral and vertical plume spread. The following options were included:

- Final plume rise
- Stack-tip downwash
- Buoyancy-induced dispersion
- Default wind speed profile exponents
- Default vertical potential temperature gradients
- Calms processing routine
- "Upper Bound" values for supersquat buildings
- No exponential decay for rural mode

Each individual emission point source with significant emissions was modeled for each emitted pollutant. Both on-site and off-site impacts from these emission sources were estimated.

Because some of the stacks were found to be subject to building downwash (i.e., stack height less than good engineering practice stack height), the controlling building dimensions were entered as input into the ISC2 dispersion analysis to determine pollutant concentrations in the presence of building wake effects. More than 50 buildings within the Site facility that meet the "nearby" criteria found in Section 123 of the Clean Air Act. According to 40 CFR 51.1(jj), the term "nearby" is defined as any structure within five times the lesser height or width dimension of that structure and within 0.5 miles of the affected stack. Trinity Consultant's Breeze Wake/Building Profile Input Program computer software was used to determine direction-specific building dimensions (height, projected width, and good engineering practice stack height) and dimensions of any wake regions.

A cavity impact analysis was performed to determine whether the stack effluents would be

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recirculated in cavity zones, and the maximum pollutant levels in the cavity were estimated. The cavity analysis was conducted using the cavity screening procedure incorporated in the latest version of the EPA SCREEN2 model.

The land use within a 1.85-mile radius of the Site (using the EPA–recommended Auer's technique) is considered to be rural. Therefore, the Pasquill-Gifford rural dispersion coefficients were used in all of the nonradiological air quality dispersion analyses.

FUGITIVE DUST MODELING. The 1991 revised version of the EPA Fugitive Dust Model (FDM) was used to assess the impact of particulate matter less than 10 micrometers (PM-10) and total suspended particulate emissions from the proposed construction and environmental restoration activities. FDM is a computerized dispersion model specifically designed for estimation of concentration and deposition impacts from fugitive dust sources. The model is generally based on the Gaussian algorithm for computing concentrations and improved gradient-transfer deposition formulation. Emissions for each source are apportioned into a series of particle classes. A gravitational settling velocity and a deposition velocity are calculated by FDM for each particle class. Because emission rates of fugitive dust are often wind dependent, FDM has the capability to directly compute the effect of wind speed on emission rate.

The primary choices for source type in the FDM model are line and area sources. The line sources are treated virtually the same as in the CALINE3 algorithm (Benson 1979). Area sources are modeled as a series of line sources perpendicular to the wind direction. The receptor is allowed to be within the area source, but only the portion of the area source upwind of the receptor is modeled.

The Closure Case analysis included simultaneous modeling of emissions from all future activities on the Site as well as emissions from remediation- and construction-related traffic traveled on the roads inside the Site boundary. The analysis of each activity consisted of modeling the PM-10 and total suspended particulate emissions for the 24 hour and the annual time periods, the periods corresponding to the applicable ambient air quality standards. An EPA-approved persistence factor of 1.75 was used to adjust model-estimated 24-hour values to 8-hour concentrations for comparison with occupational standards.

Dust emissions resulting from excavation, scraping, dozer and grader operations, and areas exposed to wind erosion were modeled as area sources, and dust from cars and trucks traveling on the paved and unpaved roadways was analyzed as line source emissions. The areas considered for the estimation of daily emission rates were assumed to be smaller than the areas considered for the estimation of annual rates. If an activity is anticipated to last more than 200 days, the daily areas were assumed to be proportional to the number of days of operation. For a short-time activity, the daily area was conservatively estimated to be one-quarter of the total remediation area. The modeling of the truck travel on the Site roadways was performed assuming that each roadway is two-directional, with one lane in either direction. PM-10 was assumed to constitute 44% of the total suspended particulate. This assumption was based on an analysis of the on-site ambient monitoring data.

The 24-hour and the annual impacts from remediation and construction activities were obtained directly from FDM output. These values were then added to the appropriate Baseline Case levels of PM-10 and total suspended particulate to obtain total concentration estimates. Total pollutant levels were then compared with the appropriate ambient air quality standards.

COMPLEX TERRAIN MODELING. Complex terrain is defined by EPA as terrain that exceeds the height of the source stack being modeled. A conservative screening-level analysis was therefore conducted to ensure that the air quality levels at receptors located at these elevated locations to the west of the Site would also not exceed the appropriate standards and guidelines.

The EPA SCREEN2C air quality screening model was used to conservatively estimate maximum 24-hour impacts at receptor located above stack height. The SCREEN2C model uses the EPA Valley Model algorithm that has been validated to yield the maximum daily impacts in complex terrain for receptors that approach or exceed final plume height. Conservative persistence factors were used to estimate the short-term (1-hour, 3-hour, and 8-hour) impacts from the 24-hour impacts. For example, maximum 1-hour impacts are assumed to be four times the 24-hour values. This correction factor is based upon the persistence factor (0.25) that the EPA Valley Model uses for calculating the maximum daily impacts in complex terrain. The Valley Model correction factor assumes that during any given day worst case meteorological conditions will occur for only six hours and, during this period, the stack plume is assumed to impact directly upon the complex terrain receptor. During the remainder of the day, the stack plume is assumed not to impact upon the receptor. The 3-hour and 8-hour persistence factors were then calculated from the 1-hour concentration as recommended in EPA's *Screening Procedures for Estimating the Air Quality Impacts for Stationary Sources* (EPA 1988). A factor of 0.9 was used to estimate 3-hour values, and a factor of 0.7 was used to estimate 8-hour values.

Annual pollutant impacts were estimated using annual source emissions data and a conservative correction factor of 3.87% to reflect actual meteorological conditions at the Site. The factor was developed based on the percentage of time that the wind blows from the emission source toward the elevated complex terrain receptors under wind speeds that would cause an impact at these receptors. Based on five years of on-site meteorological data (1989-1993), it was calculated that the wind blows in the critical direction (i.e., either west, west-southwest, or west-northwest) at wind speeds between one and seven miles per hour a maximum of 3.87% of the time.

A modified approach was required to estimate the impacts of the Site's beryllium emissions on the complex terrain receptors. Because there are numerous small sources of beryllium scattered throughout the Site, these emissions were modeled as a 500-meter square area source. Because the complex terrain methodology previously described cannot be used directly to estimate impacts from area sources, maximum 24-hour beryllium impacts were conservatively estimated using the Valley Model algorithm in SCREEN2 together with worst-case meteorology appropriate for the Valley Model complex terrain analysis (i.e., stable atmospheric conditions and 2.5 meter per second wind speeds). Impacts for the other time periods (one-hour, eight-hour, and annual) were then estimated from the 24-hour values using the same correction factors previously discussed.

B-3.1.2 Applicable Air Quality Standards and Guidelines

Three types of air quality standards and/or guidelines were considered for the nonradiological air quality analysis. These include the National Ambient Air Quality Standards (NAAQS); workplace standards developed by the Occupational Safety and Health Administration (OSHA) and/or the National Institute for Occupational Safety and Health (NIOSH); the American Conference of Governmental Industrial Hygienists (ACGIH); and ambient levels for hazardous air pollutants developed by various state agencies.

NATIONAL AMBIENT AIR QUALITY STANDARDS. The NAAQS are federally specified pollutant concentrations not to be exceeded at reasonable locations where the public has access. Time frames, based on how these pollutants adversely affect human health, have been established for these pollutants. Both primary and secondary air quality standards have been established. The primary standards were developed to protect public health; the secondary standards were developed to protect the nation's resources and account for the effect of air pollution on soil, water, vegetation, and other aspects of general welfare. The ambient air quality standards used for comparison purposes in the nonradiological air quality analysis are presented in Table B-20.

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Table B-20. National Ambient Air Quality Standards

Pollutant	Averaging Time	Standard (ug/m^3)
Sulfur Dioxide	3-hour 24-hour Annual	1,300[1] 365 80
Particulate Matter (PM-10)[2]	24-hour Annual	150 50
Nitrogen Dioxide	Annual	100
Carbon Monoxide	1-hour 8-hour	40,000 10,000
Total Suspended Particulates (TSP)[3]	24-hour Annual	260 75
Lead[3]	Monthly	1.5
Ozone	1-hour	235

[1]The 3-hour sulfur dioxide standard is a secondary standard.
[2]Particulate matter less than 10 microns.
[3]State of Colorado Standard.

OCCUPATIONAL SAFETY AND HEALTH EXPOSURE STANDARDS. OSHA and the ACGIH have established exposure standards that are specified exposure limits for hazardous substances or conditions in the workplace. These standards apply to personnel working within the Site boundary. Exposure limits are pollutant concentrations that must not be exceeded during any 8-hour work shift of a 40-hour work week. These standards are less stringent than the ambient air quality guideline values and were compared with estimated on-site concentrations for each pollutant. A list of the applicable occupational standards used for the on-site worker impact analysis is shown in Table B-21.

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Table B-21. Occupational Exposure Standards for Pollutants Emitted from the Site

Pollutant	8-Hour OSHA Standards (ug/m^3)[1]
Ammonia[2]	17,000
Benzo(a)pyrene[3]	200
Beryllium	2
Carbon Monoxide	40,000
Carbon Tetrachloride	12,600
Chlorine	1,500
Chloroform	9,780
Dioctyl Phthalate	5,000
Hydrochloric Acid	7,000
Hydrofluoric Acid	2,500
Hydrogen Sulfide	14,000
Lead	50
Methyl Ethyl Ketone	590,000
Methylene Chloride	1,765,000
Nitric Acid	5,000
Nitrogen Dioxide	5,600
Particulate Matter (PM-10)	5,000
Sulfur Dioxide	5,000
Tetrachloroethylene	689,000
Total Suspended Particulates (TSP)	15,000
1,1,1-Trichloroethane	1,900,000

[1]All occupational exposure values represent OSHA standards, unless otherwise specified.
[2]Threshold limit value established by the ACGIH.
[3]Threshold limit value established by the ACGIH for polycyclic aromatic hydrocarbons was applied to benzo(a)pyrene.

<u>Hazardous Pollutant Guidelines and Recommended Values.</u> The levels of hazardous air pollutants in the atmosphere, their potential risk, and methods for their control are currently under study by experts throughout the country. Except for beryllium and hydrogen sulfide, Colorado has not developed or promulgated air quality guidelines or standards for hazardous air pollutants, and no federal standards have been promulgated for ambient levels of these pollutants. A number of other state environmental agencies, however, have established acceptable ambient level guidelines for these pollutants.

Therefore, air quality guidelines established by several other states were compiled and reviewed. These states include Arkansas, New York, Kansas, Idaho, Texas, Connecticut, Maine, Massachusetts, Missouri, Minnesota, Michigan, and Florida. These guidelines were established for 1-hour, 8-hour, 24-hour, and annual time periods. Table B-22 presents the range of long-term and short-term guideline values established for each pollutant considered in this analysis. These guideline values can vary greatly from state to state. To ensure conservative results, recommended values were developed that are, in general, the lowest (i.e., most restrictive) value for each time period for each pollutant that may be released to the atmosphere under any of the *CID* cases. In several instances, however, the values established by the State of Texas were not consistent with those for all of the other states, thus, they were not used. The results of the modeling analysis for the Site were compared with these recommended values.

Table B-22. State Guidelines for Comparison of Off-Site Hazardous Air Pollutants Impacts

Pollutant	Time Period	Selected State Guideline Values (ug/m^3)													Recommended (ug/m^3)
		AR	KS	NY	MN	TX	ME	MA	NC	CT	FL	MI	MO	ID	
Ammonia	< 1-hr			4,000		170			2,700	1,800					1,800
	8-hrs									360	170			180	170
	24-hrs						100	4.73			40.8	10	4.73		4.73
	Annual			360	100	17	100	4.73							4.73
Benzo(a)pyrene	< 1-hr	0.79				150									0.79
	8-hrs									0.1			0.006		0.006
	24-hrs	0.21											0.006		0.006
	Annual	6×10^{-4}	3×10^{-4}	0.002		1.5	6×10^{-4}		0.033		3×10^{-4}	5×10^{-4}		3×10^{-4}	0.0003
Beryllium	< 1-hr			0.05						0.05					0.05
	8-hrs									0.01	0.02				0.01
	24-hrs						18	0.001			0.005				0.001
	Annual		4×10^{-4}	4×10^{-4}	0.004		4×10^{-4}	4×10^{-4}	0.004		4×10^{-4}	4×10^{-4}		0.004	0.0004
Carbon Tetrachloride	< 1-hr			1,300		126				1,500					1,300
	8-hrs									300	310				300
	24-hrs						860	85.52			74.4		85.52		74.4
	Annual		0.7	0.07	0.7	13	0.07	0.07	0.07		0.07	0.4		0.07	0.07
Chlorine	< 1-hr			350		15	300		900	300					300
	8-hrs									60	15			30	15
	24-hrs						60	3.95	37.5		3.6	15	3.95		3.6
	Annual			3.5		1.5	6	3.95			0.4				0.4
Chloroform	< 1-hr			980		98				1,250					980
	8-hrs									250	490				250
	24-hrs						210	132.8			117.6				117.6
	Annual		0.04	23	0.4	9.8	0.04	0.04	4.3			0.4		0.043	0.04
Dioctyl Phthalate	< 1-hr			1,200											1,200
	8-hrs														
	24-hrs														
	Annual			12											12
Hydrochloric Acid	< 1-hr			150		75			700						150
	8-hrs										75				75
	24-hrs							2.03			18	7	2.03		2.03
	Annual			7	7	0.1		2.03			7			7.5	2.03
Hydrofluoric Acid	< 1-hr					4.9			250	250		26			26
	8-hrs									50	26				26
	24-hrs							0.68	30		6.24		0.68		0.68
	Annual							0.34							0.34
Hydrogen Sulfide[1]	< 1-hr					7	2,100		2,100	1,400					142
	8-hrs									280	140				140
	24-hrs						9	3.79			33.6	0.9	3.79		3.79
	Annual				0.9		0.9	3.79			0.9				0.9

Methyl Ethyl Ketone	< 1-hr 8-hrs 24-hrs Annual	4,700		1,970	1,000	3,900 590	88,500 3,000 300	32.1	59,000	59,000 11,800 3,700	5,900 1,416 80	1,000	2,350 360	5,900	88,500 2,350 360 32.07
Methylene Chloride	< 1-hr 8-hrs 24-hrs Annual				3,000	260 26	2,300 2		24	35,000 7,000	1,740 417.6 2.1			0.24	260 1,740 417.6 2
Nitric Acid	< 1-hr 8-hrs 24-hrs Annual			12 0.12		52 5.2	1,000 87		1,000	500 100	310 74.4	50	66.67	50	500 100 50 0.12
Tetrachloroethylene	< 1-hr 8-hrs 24-hrs Annual	11,000 770 2.1	1.05	81,000 0.075	17.2	340 34	4,000 0.01	922 0.02	59	1700	3390 814	1.7	922	2.1	11,000 1,700 770 0.01
1,1,1-Trichloroethane	< 1-hr 8-hrs 24-hrs Annual			45,000 1,000	1,000	10,800 1,800 1,000	250,000 1,800 1,000	1,038 1,038		190,000 38,000	38,200 9,168		1,040	270,000	190,000 38,000 1,040 1,000

[1]The 1-hour State of Colorado ambient standard for hydrogen sulfide of 142 ug/m^3 was used as a recommended value.

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B-3.1.3 Receptors

POINT SOURCE ANALYSIS. Receptor locations for the ISC2 air quality dispersion modeling analyses were selected based on the procedures outlined in EPA's *Guideline on Air Quality Models* (EPA 1993b), using a grid layout pattern (with the center of the grid being the center of the Site) and discrete receptor points. Both on-site and off-site receptors were considered.

On-site receptors were located both in a polar grid pattern within the Site boundary and at discrete receptor points where it is reasonable to expect that personnel will be exposed for extended time periods. These discrete receptor locations included building entrances, walkways, and other areas of high employee traffic. The on-site receptor grid consisted of concentric rings, with the first ring being placed at 100 meters from the center of the Site. Subsequent rings were spaced at 100-meter intervals until reaching a distance of 2 kilometers from the center of the Site. A total of 782 receptor locations was placed within the facility boundary to estimate on-site pollutant impacts.

Off-site concentrations were estimated at 758 receptor locations. These locations were spread out from the Site in all directions to a distance of 35 kilometers and include 36 locations along the Site boundary and nine locations in nearby towns. Off-site receptors were located both in a grid pattern around the facility (with the center of the grid being the center of the Site) and at discrete receptor points. These receptor points included sensitive land use areas near the facility's property boundary (primarily residential areas), and nearby population centers of Denver, Boulder, Arvada, Northglenn, Broomfield, Lafayette, Louisville, Westminster, and Golden. The off-site receptor grid consisted of concentric rings, with the first ring being placed along the facility boundary (at approximately 1.8 kilometers from the center of the Site). Subsequent rings were spaced at 100-meter intervals until reaching a distance of 2 kilometers from the center of the Site. Between 2 kilometers and 10 kilometers from the center of the Site, the ring spacing for the receptor grid was every 500 meters. Points in the receptor grids were spaced at 10-degree intervals.

If the predicted pollutant impact at the distance of 10 kilometers was more than 10% of applicable standards or guidelines, grid spacing was continued, in 5 kilometer increments, until estimated impacts were below 10% of applicable regulatory guidelines.

FUGITIVE DUST ANALYSIS. Sensitive receptors were placed on-site and off-site the Site boundary for all FDM modeling. The off-site receptors generally followed the receptor placement in the point source analysis noted above. The receptors were located at the Site boundary, at the nearby towns and at the 10-kilometer ring around the Site. The on-site receptors were situated around the areas of activities and along the roadways where the traffic associated with the environmental restoration and construction activities will travel. The on-site receptors around the areas of operations were placed at the 50, 100, and 150 meters from each side of the emission source.

COMPLEX TERRAIN ANALYSIS. The Site is approximately 6,050 feet above mean sea level with lower elevation topography to the north, east, and south. Elevations range from 5,800 feet to the north, 5,700 feet to the east, and 5,900 feet to the south. To the west, however, the terrain gradually rises as it approaches the Rocky Mountains, which is the area considered in this complex terrain analysis. At the western edge of the Site the terrain rises to 6,150 feet and higher. High terrain is found along and west of Coal Creek, approximately 5 kilometers west of the Site, where the elevation abruptly rises to 6,300 feet. Closer to the western edge of the Site is an unnamed small hill that also rises above 6,300 feet and is located 4 kilometers west of the Site.

The screening level analysis for complex terrain assumes that the wind is blowing from the emission source directly toward each receptor for a six-hour period in any 24-hour analysis period. In addition, the terrain rises with distance from the emission source. Therefore, the location of the elevated terrain receptor closest to the emission source at each elevation would result in the highest predicted air quality impacts at that terrain. To ensure conservative results, elevated receptors were placed every 250 meters from the western boundary of the Site to the peak of the unnamed hill 4 kilometers from the source, and then every 1 kilometer along Coal Creek into the Rocky Mountains, out to 10 kilometers from the source.

B-3.1.4 Meteorological Parameters

The meteorological data used in the ISC2 and FDM air quality modeling analyses were the latest five years (1989-1993) obtained from the National Climatic Data Center for Denver's Stapleton Airport, combined with on-site observations from a 61-meter meteorological tower for the same time period. The hourly surface wind speed, wind direction, horizontal direction variation, and temperature from the on-site data were integrated with the Stapleton airport mixing height data. The hourly horizontal wind direction variation (sigma theta) was converted to the Pasquill-Gifford stability classes using EPA-accepted methodology. EPA regulatory default wind and temperature vertical profiles were utilized in the modeling analysis. The complex terrain analysis assumed worse-case meteorological conditions as described in Section B-3.1.1.

B-3.1.5 Stack Parameters

Point source emission (stack) parameters for the dispersion analysis were obtained primarily from the Site Air Pollutant Emission Notices (APENs), which included the following information:

- Stack (vent) exit velocities at maximum and average loads
- Inside stack diameters at stack top
- Stack heights above grade
- Stack gas exit temperatures
- Location of stacks

For sources such as diesel emergency generators that do not have stack gas velocity and temperature reported on the APEN, the stack parameters were calculated based on the type of engine and maximum hourly fuel consumption. For sources with non-vertical stacks, the following assumptions were made: 1) sources that have horizontal stacks will be considered to have exit velocities of zero; and 2) sources that have stacks that release downward were considered to have zero exit velocity and zero stack height.

The screening level complex terrain analysis conservatively assumes that all emissions of each pollutant are emitted from one representative emission point. Composite stack (vent) and associated emission parameters were developed, based on the types of sources, for each pollutant identified. For the criteria pollutants (i.e., nitrogen dioxide, sulfur dioxide, and carbon monoxide), emissions were associated mostly with the operation of the facility's heating plant. These emissions are released primarily through tall heating plant stacks. The hazardous air pollutant releases, on the other hand, are released to the atmosphere at lower heights, and each hazardous air pollutant was modeled based upon the operating parameters that best represented the emission of that pollutant.

B-3.2 Baseline and Closure Cases Scenario Descriptions

B-3.2.1 Nonradiological Air Emission Inventory

The following procedures were used to select the emission sources that were considered for Site nonradiological air quality impact analysis for the Closure Case. The approach outlined for point sources applies to the ISC2 and complex terrain modeling, and the procedures presented for fugitive dust sources supported the FDM modeling analysis.

<u>POINT SOURCES.</u> Point sources of air pollution emissions at the Site include combustion sources such as boilers and emergency generators, which primarily emit criteria pollutants, and laboratories and waste management operations, which primarily emit hazardous pollutants. Annual emission data for the Site were obtained from the APEN forms prepared by the Site and submitted to the Colorado Department of Public Health and Environment. Since current APEN forms do not include emissions from exempt source categories, such as laboratories, historical APEN forms, and internal air emission update reports by the Site were used to obtain annual emissions rates for

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these sources.

Because the APEN forms report only annual emissions from a source, maximum hourly emission rates needed for estimating short-term (1-hour, 3-hour, 8-hour, and 24-hour) concentrations were calculated using information from the APEN forms. The assumptions and emissions factors used were those used by the Site in preparing the original APENs. For sources that were not permitted, reported annual and maximum hourly emission rates were used. For sources that had State of Colorado air emission permits, permitted annual emissions, which are higher than actual emissions, were used instead of actual annual emissions.

Each individual emission point with uncontrolled actual emissions of 1 ton per year or more of any criteria pollutant was included in the emission inventory. This threshold is the same as the reporting threshold in Colorado Air Quality Control Commission (CAQCC) Regulation No. 3. For combustion sources, such as diesel- and natural-gas-fired engines, all criteria pollutant emissions from each source were included in the inventory regardless of whether they met the one ton per year threshold.

For hazardous air pollutants, a tiered approach was used to identify potentially significant air emission sources. The first step in the screening process was to sum the site-wide emissions for each individual pollutant to obtain a Site total for that pollutant. (This total includes emissions from exempt source categories in CAQCC Regulation No. 3.) If the total amount of uncontrolled emissions for a pollutant was above the lowest reporting threshold level in CAQCC Regulation No. 3 of 50, 500, and 1,000 pounds per year for Bins A, B, and C category pollutants, respectively, all individual emission sources of that pollutant were included in the air quality assessment, without regard for how much was released from each individual source.

A total of 21 air pollutants was found to be emitted from the Site facilities in quantities exceeding the threshold levels described above. These pollutants include both criteria pollutants and hazardous air pollutants. The criteria pollutants include carbon monoxide, nitrogen dioxide, sulfur dioxide, lead, and PM-10. TSP is designated as a criteria pollutant by the State of Colorado. Ozone, another criteria pollutant, was not specifically addressed in this analysis because it is a pollutant that is formed in the atmosphere far downwind of emission sources and is usually analyzed on a regional basis. In addition, volatile organic compounds, one of the precursors of ozone in the atmosphere, are emitted from Site activities in quantities below State of Colorado major source threshold limits of 100 tons per year as specified in CAQCC Regulation No. 7.

Beryllium emissions were continuously sampled and reported at 53 separate locations around the Site. In 1992, total controlled beryllium emissions from the Site were measured to be 7.6×10^{-3} pounds per year. Due to the large number of beryllium emission points spread over the facility and the very small amount of emissions from each individual source, the approach for the Baseline Case air quality evaluation for this pollutant was to model all existing beryllium emission sources as an area source. This approach is conservative in assessing impacts from beryllium emissions while minimizing the time and expense of separately modeling all 53 beryllium emission points.

An emissions inventory for the Site under existing conditions was developed. This inventory includes all reportable pollutants and emission sources subject to applicable federal and state regulatory requirements, as well as some emission sources that are currently exempt from reporting requirements under CAQCC Regulation No. 3. Calendar year 1994 was established as the year for determining the Baseline Case conditions at the Site. Sources no longer in operation as of June 1996 were removed from the Site emission inventory to form the source inventory under Baseline Case conditions.

Point source emissions were also for the Closure Case. Emissions for point sources that did not exist under existing conditions were estimated based on emissions from similar facilities at the Site or at other DOE sites. If no similar facilities exist, process information and engineering assumptions were used to estimate emissions. For the existing point sources that were included in the emissions inventory for which emissions would either increase or decrease under future conditions, emissions were scaled based on process knowledge.

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Annual and hourly emissions for each pollutant on a site-wide basis are presented in Table B-23 for Baseline Case conditions and the Closure Case. Emissions estimates for each individual point source under Baseline Case conditions and the Closure Case are presented in Tables B-24 and B-25 for combustion and non-combustion sources, respectively.

Table B-23. Annual and Hourly Point Source Emissions of Air Pollutants from Site Activities Under Baseline Case Conditions and the Closure Case

Pollutants[2]	Annual Average Emissions[1] (tpy)		Maximum Hourly Emissions[1] (lbs/hr)	
	Baseline Case	Closure Case	Baseline Case	Closure Case
Ammonia	0.71	0.71	0.71	0.71
Benzo(a)pyrene[3]	–	5.0×10^{-4}	–	5.0×10^{-4}
Beryllium	3.8×10^{-6}	1.5×10^{-5}	3.8×10^{-6}	1.5×10^{-5}
Carbon Monoxide	41.0	42.0	191	192
Carbon Tetrachloride	0.18	0.31	0.09	0.21
Chloroform	0.36	0.36	0.36	0.36
Chlorine	0.11	0.11	0.03	0.03
Dioctyl Phthalate	0.01	0.01	0.01	0.01
Hydrochloric Acid	0.27	0.52	0.17	0.42
Hydrofluoric Acid	0.10	0.10	0.05	0.05
Hydrogen Sulfide	1.06	1.06	0.26	0.26
Lead	1.7×10^{-12}	1.7×10^{-12}	1.7×10^{-12}	1.7×10^{-12}
Methyl Ethyl Ketone[4]	–	0.13	–	0.13
Methylene Chloride	0.47	0.59	0.37	0.50
Nitric Acid	2.11	2.23	1.14	1.26
Nitrogen Dioxide	172	176	861	865
Sulfur Dioxide	11.2	12.2	532	533
Tetrachloroethylene[3]	–	0.13	–	0.13
1,1,1-Trichloroethane	1.21	1.33	4.94	5.06

[1]Hourly emissions of criteria pollutants from steam plant operations were estimated based on burning No. 6 fuel oil while annual emissions are based on burning natural gas.

[2]PM-10 and TSP emissions from point sources were not used in the dispersion modeling analysis. For the Baseline Case conditions, Site ambient air quality impacts were based on ambient monitoring data as presented in Section 4.5. PM-10 and TSP emissions are presented in Tables H-24 the Closure Case.

[3]Pollutant not emitted under the Baseline Case conditions but is included in the air quality impact analysis the Closure Case.

[4]Pollutant not emitted under the Baseline Case conditions but is included in the air quality impact analysis for the Closure Case.

Table B-24. Combustion Source Emission Inventory for Baseline and Closure Cases

Building Vent Number	Source Description	Pollutant	Baseline and Closure Cases: Hourly Emissions (lbs/hr)	Baseline and Closure Cases: Annual Emissions (tpy)
120	Emergency Generator Generac D80/2120 engine	CO	6.53×10^{-1}	8.16×10^{-2}
	100 hp, fuel consumption rate (F.C.R.) = 6.4 gal/hr	VOC	2.85×10^{-1}	3.56×10^{-2}
		NOX	3.04	3.80×10^{-1}
		SO2	2.00×10^{-1}	2.50×10^{-2}
		TSP	2.14×10^{-1}	2.68×10^{-2}
		PM-10	2.05×10^{-1}	2.56×10^{-2}
124-2	Emergency Generator Cummins NT 400 engine	CO	1.60	2.00×10^{-1}
	F.C.R. = 16 gal/hr	VOC	7.13×10^{-1}	8.91×10^{-2}
		NOX	7.52	9.40×10^{-1}
		SO2	4.99×10^{-1}	6.24×10^{-2}
		TSP	5.36×10^{-1}	6.70×10^{-2}
		PM-10	5.12×10^{-1}	6.40×10^{-2}
127-6	Emergency Generator Caterpillar 3408 engine	CO	3.12	3.90×10^{-1}
	410 hp, F.C.R. = 30.9 gal/hr	VOC	1.36	1.70×10^{-1}
		NOX	14.5	1.81
		SO2	9.60×10^{-1}	1.20×10^{-1}
		TSP	1.04	1.30×10^{-1}
		PM-10	9.60×10^{-1}	1.20×10^{-1}
371-41	Emergency Generator Detroit 40-501RB engine	CO	35.8	4.47
	2,500 hp, F.C.R. = 275 gal/hr	VOC	3.60	4.50×10^{-1}
		NOX	138	17.2
		SO2	16.5	2.06
		TSP	13.8	1.72
		PM-10	12.6	1.58
372A	Emergency Generator Generac 88A02361-S	CO	6.53×10^{-1}	8.16×10^{-2}
	107 hp, F.C.R. = 6.4 gal/hr	VOC	2.85×10^{-1}	3.56×10^{-2}
		NOX	3.04	3.80×10^{-1}
		SO2	2.00×10^{-1}	2.50×10^{-2}
		TSP	2.14×10^{-1}	2.68×10^{-2}
		PM-10	2.05×10^{-1}	2.56×10^{-2}
373-1	Diesel Pump Detroit VT16-71 engine	CO	3.90	1.95
	300 hp, F.C.R. = 30 gal/hr	VOC	4.40×10^{-1}	2.20×10^{-1}
		NOX	15.0	7.50
		SO2	1.80	9.00×10^{-1}
		TSP	1.50	7.50×10^{-1}
		PM-10	1.38	6.90×10^{-1}

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427-5	Emergency Generator Caterpillar 3412 engine	CO	5.52	6.90×10^{-1}
	908 hp, F.C.R. = 42.7 gal/hr	VOC	5.55×10^{-1}	6.94×10^{-2}
		NOX	21.4	2.67
		SO2	2.56	3.20×10^{-1}
		TSP	2.16	2.70×10^{-1}
		PM-10	2.00	2.50×10^{-1}
443-15	Emergency Generator #2 Caterpillar D348 engine	CO	4.72	5.90×10^{-1}
	710 hp, F.C.R. = 36 gal/hr	VOC	4.68×10^{-1}	5.85×10^{-2}
		NOX	18.0	2.25
		SO2	2.16	2.70×10^{-1}
		TSP	1.84	2.30×10^{-1}
		PM-10	1.76	2.20×10^{-1}
443-30,31	Emergency Generator #1 Detroit V16-92T engine	CO	5.84	7.30×10^{-1}
	710 hp, F.C.R. = 45 gal/hr	VOC	5.85×10^{-1}	7.31×10^{-2}
		NOX	22.5	2.81
		SO2	2.72	3.40×10^{-1}
		TSP	2.24	2.80×10^{-1}
		PM-10	2.16	2.70×10^{-1}
443-44	Steam Plant Boilers #4 Natural Gas	CO	3.68	3.50
		VOC	2.90×10^{-1}	2.80×10^{-1}
		NOX	14.7	14.0
		SO2	6.00×10^{-2}	6.00×10^{-2}
		TSP	5.30×10^{-1}	5.00×10^{-1}
		PM-10	5.30×10^{-1}	5.00×10^{-1}
443-49	Steam Plant Boilers #5 Natural Gas	CO	3.68	3.50
		VOC	2.90×10^{-1}	2.80×10^{-1}
		NOX	14.7	14.0
		SO2	6.00×10^{-2}	6.00×10^{-2}
		TSP	5.30×10^{-1}	5.00×10^{-1}
		PM-10	5.30×10^{-1}	5.00×10^{-1}
443-50	Steam Plant Boilers #6 Natural Gas	CO	3.68	3.50
		VOC	2.90×10^{-1}	2.80×10^{-1}
		NOX	14.7	14.0
		SO2	6.00×10^{-2}	6.00×10^{-2}
		TSP	5.30×10^{-1}	5.00×10^{-1}
		PM-10	5.30×10^{-1}	5.00×10^{-1}
443-86	Steam Plant Boilers #7 Natural Gas	CO	3.68	3.50
		VOC	2.90×10^{-1}	2.80×10^{-1}
		NOX	14.7	14.0
		SO2	6.00×10^{-2}	6.00×10^{-2}
		TSP	5.30×10^{-1}	5.00×10^{-1}
		PM-10	5.30×10^{-1}	5.00×10^{-1}
443-44	Steam Plant Boilers #4 No. 6 Fuel Oil	CO	3.57	2.50×10^{-2}
		VOC	2.00×10^{-1}	1.40×10^{-3}
		NOX	39.3	2.80×10^{-1}
		SO2	114	8.00×10^{-1}

		TSP	9.29	6.50×10^{-2}
		PM-10	8.36	5.85×10^{-2}
443-49	Steam Plant Boilers #5 No. 6 Fuel Oil	CO	3.57	2.50×10^{-2}
		VOC	2.00×10^{-1}	1.40×10^{-3}
		NOX	39.3	2.80×10^{-1}
		SO2	114	8.00×10^{-1}
		TSP	9.29	6.50×10^{-2}
		PM-10	8.36	5.85×10^{-2}
443-50	Steam Plant Boilers #6 No. 6 Fuel Oil	CO	3.57	2.50×10^{-2}
		VOC	2.00×10^{-1}	1.40×10^{-3}
		NOX	39.3	2.80×10^{-1}
		SO2	114	8.00×10^{-1}
		TSP	9.29	6.50×10^{-2}
		PM-10	8.36	5.85×10^{-2}
443-86	Steam Plant Boilers #7 No. 6 Fuel Oil	CO	3.57	2.50×10^{-2}
		VOC	2.00×10^{-1}	1.40×10^{-3}
		NOX	39.3	2.80×10^{-1}
		SO2	114	8.00×10^{-1}
		TSP	9.29	6.50×10^{-2}
		PM-10	8.36	5.85×10^{-2}
559-20	Emergency Generator Caterpillar D353 engine	CO	1.20	1.50×10^{-1}
	405 hp, F.C.R. = 12 gal/hr	VOC	5.35×10^{-1}	6.69×10^{-2}
		NOX	5.60	7.00×10^{-1}
		SO2	3.74×10^{-1}	4.68×10^{-2}
		TSP	4.02×10^{-1}	5.03×10^{-2}
		PM-10	3.84×10^{-1}	4.80×10^{-2}
562-7	Emergency Generator Detroit V16-71T engine	CO	5.20	6.50×10^{-1}
	825 hp, F.C.R. = 39.8 gal/hr	VOC	5.18×10^{-1}	6.47×10^{-2}
		NOX	19.9	2.49
		SO2	2.40	3.00×10^{-1}
		TSP	2.00	2.50×10^{-1}
		PM-10	1.84	2.30×10^{-1}
566-2	Emergency Generator Cummins DMT 175 CA	CO	1.20	1.50×10^{-1}
	264 hp, F.C.R. = 11.5 gal/hr	VOC	5.12×10^{-1}	6.40×10^{-2}
		NOX	5.36	6.70×10^{-1}
		SO2	3.59×10^{-1}	4.49×10^{-2}
		TSP	3.86×10^{-1}	4.82×10^{-2}
		PM-10	3.68×10^{-1}	4.60×10^{-2}
708-10	Emergency Generator GM EL.Mot.12-645-E1	CO	10.2	1.28
	1,500 hp, F.C.R. = 78.8 gal/hr	VOC	1.12	1.40×10^{-1}
		NOX	39.4	4.93
		SO2	4.72	5.90×10^{-1}
		TSP	3.92	4.90×10^{-1}
		PM-10	3.60	4.50×10^{-1}
708-18	Emergency Generator Caterpillar 3412 engine	CO	4.72	5.90×10^{-1}

	749 hp, F.C.R. = 36 gal/hr	VOC	4.68×10^{-1}	5.85×10^{-2}
		NOX	18.0	2.25
		SO2	2.16	2.70×10^{-1}
		TSP	1.84	2.30×10^{-1}
		PM-10	1.68	2.10×10^{-1}
708-6	Emergency Generator Caterpillar 3208 engine	CO	2.24	2.80×10^{-1}
	194 hp, F.C.R. = 22 gal/hr	VOC	9.60×10^{-1}	1.20×10^{-1}
		NOX	10.3	1.29
		SO2	6.86×10^{-1}	8.58×10^{-2}
		TSP	7.37×10^{-1}	9.21×10^{-2}
		PM-10	7.04×10^{-1}	8.80×10^{-2}
709-dctwp	Diesel Pump Cummins NTC335 engine	CO	1.04	1.30×10^{-1}
	335 hp, F.C.R. = 10 gal/hr	VOC	4.46×10^{-1}	5.57×10^{-2}
		NOX	4.72	5.90×10^{-1}
		SO2	3.12×10^{-1}	3.90×10^{-2}
		TSP	3.35×10^{-1}	4.19×10^{-2}
		PM-10	3.20×10^{-1}	4.00×10^{-2}
711-dctwp	Diesel Pump Allis Chalmers 1700 engine	CO	1.52	1.90×10^{-1}
	350 hp, F.C.R. = 15 gal/hr	VOC	6.68×10^{-1}	8.35×10^{-2}
		NOX	7.04	8.80×10^{-1}
		SO2	4.68×10^{-1}	5.85×10^{-2}
		TSP	5.02×10^{-1}	6.28×10^{-2}
		PM-10	4.80×10^{-1}	6.00×10^{-2}
715-4	Emergency Generator Detroit V12-149 engine	CO	7.44	9.30×10^{-1}
	1,300 hp, F.C.R. = 57 gal/hr	VOC	7.41×10^{-1}	9.26×10^{-2}
		NOX	28.5	3.56
		SO2	3.44	4.30×10^{-1}
		TSP	2.88	3.60×10^{-1}
		PM-10	2.64	3.30×10^{-1}
715A-1	Emergency Generator Caterpillar 3512 engine	CO	13.0	1.63
	1,904 hp, F.C.R. = 100 gal/hr	VOC	1.28	1.60×10^{-1}
		NOX	50.0	6.25
		SO2	6.00	7.50×10^{-1}
		TSP	5.04	6.30×10^{-1}
		PM-10	4.64	5.80×10^{-1}
727-2	Emergency Generator Detroit V16-71T engine	CO	4.72	5.90×10^{-1}
	750 hp, F.C.R. = 36 gal/hr	VOC	4.68×10^{-1}	5.85×10^{-2}
		NOX	18.0	2.25
		SO2	2.16	2.70×10^{-1}
		TSP	1.84	2.30×10^{-1}
		PM-10	1.68	2.10×10^{-1}
729-8	Emergency Generator Allis Chalmers engine	CO	1.12	1.40×10^{-1}
	276 hp, F.C.R. = 11 gal/hr	VOC	4.90×10^{-1}	6.13×10^{-2}
		NOX	5.12	6.40×10^{-1}
		SO2	3.43×10^{-1}	4.29×10^{-2}

		TSP	3.69×10^{-1}	4.61×10^{-2}
		PM-10	3.52×10^{-1}	4.40×10^{-2}
762A	Emergency Generator Generac 88A02395-S	CO	6.53×10^{-1}	8.16×10^{-2}
	107 hp, F.C.R. = 6.4 gal/hr	VOC	2.85×10^{-1}	3.56×10^{-2}
		NOX	3.04	3.80×10^{-1}
		SO2	2.00×10^{-1}	2.50×10^{-2}
		TSP	2.14×10^{-1}	2.68×10^{-2}
		PM-10	2.05×10^{-1}	2.56×10^{-2}
776-72	Emergency Generator Caterpillar 3512 engine	CO	7.84	9.80×10^{-1}
	1,300 hp, F.C.R. = 60 gal/hr	VOC	7.80×10^{-1}	9.75×10^{-2}
		NOX	30.0	3.75
		SO2	3.60	4.50×10^{-1}
		TSP	3.04	3.80×10^{-1}
		PM-10	2.88	3.60×10^{-1}
779-44	Emergency Generator Caterpillar D343A engine	CO	1.92	2.40×10^{-1}
	348 hp, F.C.R. = 18.5 gal/hr	VOC	8.00×10^{-1}	1.00×10^{-1}
		NOX	8.64	1.08
		SO2	5.78×10^{-1}	7.22×10^{-2}
		TSP	6.20×10^{-1}	7.75×10^{-2}
		PM-10	5.73×10^{-1}	7.16×10^{-2}
792A	Emergency Generator Generac 88A02361-S	CO	4.29×10^{-1}	5.36×10^{-2}
	67 hp, F.C.R. = 4.2 gal/hr	VOC	1.87×10^{-1}	2.34×10^{-2}
		NOX	2.00	2.50×10^{-1}
		SO2	1.31×10^{-1}	1.64×10^{-2}
		TSP	1.41×10^{-1}	1.76×10^{-2}
		PM-10	1.34×10^{-1}	1.68×10^{-2}
827-2	Emergency Generator Caterpillar D348 engine	CO	4.72	5.90×10^{-1}
	805 hp, F.C.R. = 36 gal/hr	VOC	4.68×10^{-1}	5.85×10^{-2}
		NOX	18.0	2.25
		SO2	2.16	2.70×10^{-1}
		TSP	1.84	2.30×10^{-1}
		PM-10	1.68	2.10×10^{-1}
881G-104	Emergency Generator Caterpillar 3516 engine	CO	5.60	7.00×10^{-1}
	2,022 hp, F.C.R. = 100 gal/hr	VOC	5.59×10^{-1}	6.99×10^{-2}
		NOX	21.5	2.69
		SO2	2.56	3.20×10^{-1}
		TSP	2.16	2.70×10^{-1}
		PM-10	2.00	2.50×10^{-1}
881G-103	Emergency Generator Caterpillar D348 engine	CO	13.0	1.63
	710 hp, F.C.R. = 43 gal/hr	VOC	1.28	1.60×10^{-1}
		NOX	50.0	6.25
		SO2	6.00	7.50×10^{-1}
		TSP	5.04	6.30×10^{-1}
		PM-10	4.64	5.80×10^{-1}

910 A	Electric Power Generator	CO	3.17×10^{-1}	5.70×10^{-1}
910 B		VOC	5.00×10^{-2}	1.20×10^{-1}
910 C		NOX	4.96	8.93
		SO2	8.94×10^{-4}	1.61×10^{-3}
		TSP	5.94×10^{-2}	1.07×10^{-1}
		PM-10	5.94×10^{-2}	1.07×10^{-1}
920	Emergency Generator Generac D80/2120 engine	CO	6.53×10^{-1}	8.16×10^{-2}
	100 hp, F.C.R. = 6.4 gal/hr	VOC	2.85×10^{-1}	3.56×10^{-2}
		NOX	3.04	3.80×10^{-1}
		SO2	2.00×10^{-1}	2.50×10^{-2}
		TSP	2.14×10^{-1}	2.68×10^{-2}
		PM-10	2.05×10^{-1}	2.56×10^{-2}
928-1	Diesel Engine Cummins NT855-F2 engine	CO	1.52	1.90×10^{-1}
	340 hp, F.C.R. = 15 gal/hr	VOC	6.68×10^{-1}	8.35×10^{-2}
		NOX	7.04	8.80×10^{-1}
		SO2	4.68×10^{-1}	5.85×10^{-2}
		TSP	5.02×10^{-1}	6.28×10^{-2}
		PM-10	4.80×10^{-1}	6.00×10^{-2}
989-5	Emergency Generator Caterpillar D343 engine	CO	1.92	2.40×10^{-1}
	425 hp, F.C.R. = 18.5 gal/hr	VOC	8.24×10^{-1}	1.03×10^{-1}
		NOX	8.64	1.08
		SO2	5.78×10^{-1}	7.22×10^{-2}
		TSP	6.20×10^{-1}	7.75×10^{-2}
		PM-10	5.92×10^{-1}	7.40×10^{-2}
Portable	Portable Generator A Caterpillar 3516 engine	CO	13.0	1.63
	1,877 hp, F.C.R. = 100 gal/hr	VOC	1.28	1.60×10^{-1}
		NOX	50.0	6.25
		SO2	6.00	7.50×10^{-1}
		TSP	5.04	6.30×10^{-1}
		PM-10	4.64	5.80×10^{-1}
Portable	Portable B Generator Caterpillar 3412 engine	CO	3.36	4.20×10^{-1}
	675 hp, F.C.R. = 33 gal/hr	VOC	1.44	1.80×10^{-1}
		NOX	15.4	1.93
		SO2	1.04	1.30×10^{-1}
		TSP	1.12	1.40×10^{-1}
		PM-10	1.04	1.30×10^{-1}
995	Sullivan Air Compressor John Deere CD9039	CO	1.03×10^{-1}	4.50×10^{-1}
	95 hp, F.C.R. = 1 gal/hr	VOC	3.20×10^{-2}	1.40×10^{-1}
		NOX	4.68×10^{-1}	2.05
		SO2	3.20×10^{-2}	1.40×10^{-1}
		TSP	3.42×10^{-2}	1.50×10^{-1}
		PM-10	3.20×10^{-2}	1.40×10^{-1}
331	Davey Air Compressor 3306 engine	CO	5.10×10^{-1}	4.59×10^{-1}
	236 hp, F.C.R. = 5 gal/hr	VOC	1.60×10^{-1}	1.44×10^{-1}
		NOX	2.34	2.11

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		SO2	1.56×10^{-1}	1.40×10^{-1}
		TSP	1.68×10^{-1}	1.51×10^{-1}
		PM-10	1.60×10^{-1}	1.44×10^{-1}
Portable	200 kW ER Generator Detroit 6-71T engine	CO	1.68	1.68
	330 hp, F.C.R. = 16.5 gal/hr	VOC	5.30×10^{-1}	5.30×10^{-1}
		NOX	7.74	7.74
		SO2	5.10×10^{-1}	5.10×10^{-1}
		TSP	5.50×10^{-1}	5.50×10^{-1}
		PM-10	5.30×10^{-1}	5.30×10^{-1}
Portable	400 kW ER Generator Detroit 8V-92TTA engine	CO	3.36	4.20×10^{-1}
	643 hp, F.C.R. = 33.2 gal/hr	VOC	1.04	1.30×10^{-1}
		NOX	15.6	1.95
		SO2	1.04	1.30×10^{-1}
		TSP	1.12	1.40×10^{-1}
		PM-10	1.04	1.30×10^{-1}
N/A	Site Wide Natural Gas Boilers w/Heaters	CO	1.64×10^{-1}	7.20×10^{-1}
	Space Heaters	VOC	3.32×10^{-2}	1.45×10^{-1}
		NOX	8.31×10^{-1}	3.64
		SO2	4.98×10^{-3}	2.18×10^{-2}
		TSP	3.32×10^{-2}	1.45×10^{-1}
		PM-10	3.32×10^{-2}	1.45×10^{-1}

Table B-25. Noncombustion Source Air Emission Inventory for Baseline and Closure Cases

Building Vent	Source Description	Pollutant ID	Baseline Case Hourly (lbs/hr)	Baseline Case Annual (tpy)	Closure Case Hourly (lbs/hr)	Closure Case Annual (tpy)
123-1	Special Analysis	Nitric Acid	2.25×10^{-4}	4.50×10^{-4}	2.25×10^{-4}	4.50×10^{-4}
123-11	Routine Environmental	Nitric Acid	2.20×10^{-1}	4.40×10^{-1}	2.20×10^{-1}	4.40×10^{-1}
		Hydrofluoric Acid	3.95×10^{-2}	7.90×10^{-2}	3.95×10^{-2}	7.90×10^{-2}
123-14	Laboratory Tests	Hydrochloric Acid	5.50×10^{-2}	1.10×10^{-1}	5.50×10^{-2}	1.10×10^{-1}
123-22	Miscellaneous Laboratory Analysis	Nitric Acid	2.90×10^{-1}	5.80×10^{-1}	2.90×10^{-1}	5.80×10^{-1}
		Hydrochloric Acid	3.15×10^{-2}	6.30×10^{-2}	3.15×10^{-2}	6.30×10^{-2}
		Hydrofluoric Acid	6.50×10^{-3}	1.30×10^{-2}	6.50×10^{-3}	1.30×10^{-2}
		Ammonia	1.25×10^{-2}	2.50×10^{-2}	1.25×10^{-2}	2.50×10^{-2}
123-27	Routine Bioassay	Nitric Acid	4.80×10^{-1}	9.60×10^{-1}	4.80×10^{-1}	9.60×10^{-1}
		Hydrochloric Acid	1.10×10^{-2}	2.20×10^{-2}	1.10×10^{-2}	2.20×10^{-2}
		Ammonia	5.50×10^{-2}	1.10×10^{-1}	5.50×10^{-2}	1.10×10^{-1}
334-13	Carpenter Shop Dust Collector	TSP	1.76	3.30×10^{-1}	1.76	3.30×10^{-1}
334 Highbay	High Bay Maintenance	1,1,1-Trichloroethane	1.41×10^{-2}	1.41×10^{-2}	1.41×10^{-2}	1.41×10^{-2}
371-1	Chemical Standards Laboratory	Nitric Acid	2.23×10^{-3}	2.23×10^{-3}	2.23×10^{-3}	2.23×10^{-3}
		Hydrochloric Acid	1.24×10^{-4}	1.24×10^{-4}	1.24×10^{-4}	1.24×10^{-4}
371-2	Analytical Support Laboratory	Nitric Acid	3.30×10^{-2}	3.30×10^{-2}	3.30×10^{-2}	3.30×10^{-2}
		Hydrochloric Acid	4.74×10^{-4}	4.74×10^{-4}	4.74×10^{-4}	4.74×10^{-4}
		Hydrofluoric Acid	1.83×10^{-5}	1.83×10^{-5}	1.83×10^{-5}	1.83×10^{-5}
442-2	Penetrometer	Dioctyl Phthalate	4.54×10^{-3}	4.54×10^{-3}	4.54×10^{-3}	4.54×10^{-3}
442-3	Penetrometer	Dioctyl Phthalate	6.83×10^{-3}	6.83×10^{-3}	6.83×10^{-3}	6.83×10^{-3}
442-8	Penetrometer	Dioctyl Phthalate	1.70×10^{-5}	1.70×10^{-5}	1.70×10^{-5}	1.70×10^{-5}
442-15	Penetrometer	Dioctyl Phthalate	1.80×10^{-4}	1.80×10^{-4}	1.80×10^{-4}	1.80×10^{-4}
460-30	Assembly Cleaning	Nitric Acid				
559-36	Analytical Laboratory	Nitric Acid	2.71×10^{-2}	2.71×10^{-2}	2.71×10^{-2}	2.71×10^{-2}
		Hydrochloric Acid	2.44×10^{-2}	2.44×10^{-2}	2.44×10^{-2}	2.44×10^{-2}
		1,1,1-Trichloroethane	1.77×10^{-2}	1.77×10^{-2}	1.77×10^{-2}	1.77×10^{-2}
		Chloroform	3.60×10^{-1}	3.60×10^{-1}	3.60×10^{-1}	3.60×10^{-1}
705-11	Parts Cleaning	Nitric Acid	3.13×10^{-3}	3.13×10^{-3}	3.13×10^{-3}	3.13×10^{-3}
		Hydrochloric Acid	2.47×10^{-3}	2.47×10^{-3}	2.47×10^{-3}	2.47×10^{-3}
		Hydrofluoric Acid	2.06×10^{-3}	2.06×10^{-3}	2.06×10^{-3}	2.06×10^{-3}
771-86	Laboratory	Hydrochloric Acid	3.17×10^{-6}	3.17×10^{-6}	3.17×10^{-6}	3.17×10^{-6}
881-5,6,7,8	Laboratory, Research and Development	Nitric Acid	4.20×10^{-2}	4.20×10^{-2}	4.20×10^{-2}	4.20×10^{-2}
		Hydrochloric Acid	4.41×10^{-2}	4.41×10^{-2}	4.41×10^{-2}	4.41×10^{-2}
		1,1,1-Trichloroethane	6.20×10^{-2}	6.20×10^{-2}	6.20×10^{-2}	6.20×10^{-2}
		Hydrogen Sulfide	5.00×10^{-3}	5.00×10^{-3}	5.00×10^{-3}	5.00×10^{-3}
		Hydrofluoric Acid	3.10×10^{-3}	3.10×10^{-3}	3.10×10^{-3}	3.10×10^{-3}
		Ammonia	6.25×10^{-2}	6.25×10^{-2}	6.25×10^{-2}	6.25×10^{-2}
		Methylene Chloride	2.80×10^{-1}	2.80×10^{-1}	2.80×10^{-1}	2.80×10^{-1}

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991-7,8,29	Metallography Laboratory	Nitric Acid	1.66×10^{-4}	1.66×10^{-4}	1.66×10^{-4}	1.66×10^{-4}
		Hydrochloric Acid	1.31×10^{-7}	1.31×10^{-7}	1.31×10^{-7}	1.31×10^{-7}
		Hydrofluoric Acid	1.09×10^{-4}	1.09×10^{-4}	1.09×10^{-4}	1.09×10^{-4}
Site-wide	Beryllium Operations	Beryllium	3.80×10^{-6}	3.80×10^{-6}	3.80×10^{-6}	3.80×10^{-6}
Waste Management						
374	Tank 167	Nitric Acid	3.85×10^{-2}	8.00×10^{-3}	3.85×10^{-2}	8.00×10^{-3}
374-3	Spray Dryer	Ammonia	1.60×10^{-1}	9.20×10^{-2}	1.60×10^{-1}	9.20×10^{-2}
		TSP	2.47×10^{-5}	1.42×10^{-5}	2.47×10^{-5}	1.42×10^{-5}
374-7,8,9	Waste Receiving	Nitric Acid	3.08×10^{-3}	1.35×10^{-2}	3.08×10^{-3}	1.35×10^{-2}
		Hydrochloric Acid	1.74×10^{-4}	7.61×10^{-4}	1.74×10^{-4}	7.61×10^{-4}
774-4	Organic Sludge Immobilization	1,1,1-Trichloroethane	4.67	8.40×10^{-1}	4.67	8.40×10^{-1}
776-32	Supercompactor and Waste Shredder	1,1,1-Trichloroethane	1.50×10^{-1}	1.50×10^{-1}	1.50×10^{-1}	1.50×10^{-1}
		Carbon Tetrachloride	5.94×10^{-2}	5.94×10^{-2}	5.94×10^{-2}	5.94×10^{-2}
		Methylene Chloride	6.10×10^{-2}	6.10×10^{-2}	6.10×10^{-2}	6.10×10^{-2}
		Lead	1.69×10^{-12}	1.69×10^{-12}	1.69×10^{-12}	1.69×10^{-12}
		TSP	1.57×10^{-11}	1.57×10^{-11}	1.57×10^{-11}	1.57×10^{-11}
T974	Sludge Dryer	Hydrogen Sulfide	1.20×10^{-2}	1.20×10^{-2}	1.20×10^{-2}	1.20×10^{-2}
		Ammonia	2.40×10^{-1}	2.40×10^{-1}	2.40×10^{-1}	2.40×10^{-1}
T974A	Belt Filter Press	Hydrogen Sulfide	8.80×10^{-3}	8.80×10^{-3}	8.80×10^{-3}	8.80×10^{-3}
		Ammonia	1.80×10^{-1}	1.80×10^{-1}	1.80×10^{-1}	1.80×10^{-1}
995	Sewage Treatment Site Operations	Hydrogen Sulfide	2.35×10^{-1}	1.03	2.35×10^{-1}	1.03
		Ammonia	6.19×10^{-4}	2.71×10^{-3}	6.19×10^{-4}	2.71×10^{-3}
		Chlorine	2.51×10^{-2}	1.10×10^{-1}	2.51×10^{-2}	1.10×10^{-1}
371-1	Combustible and Fluoride Residue Processing	Hydrochloric Acid			1.25×10^{-1}	1.25×10^{-1}
		Nitric Acid			1.25×10^{-1}	1.25×10^{-1}
729-12	Salt Residue Processing	Carbon Monoxide			1.00	1.00
771-86	Actinide Solution Stabilization	Hydrochloric Acid			1.25×10^{-1}	1.25×10^{-1}
776-32	Drum Venting and Repackaging	Carbon Tetrachloride	2.85×10^{-2}	1.25×10^{-1}	2.85×10^{-2}	1.25×10^{-1}
		Methylene Chloride	2.85×10^{-2}	1.25×10^{-1}	2.85×10^{-2}	1.25×10^{-1}
		1,1,1-Trichloroethane	2.85×10^{-2}	1.25×10^{-1}	2.85×10^{-2}	1.25×10^{-1}
774-4	Microwave Solidification	NOx			4.00	4.00
		SO_2			1.00	1.00
776-32	Surface Organic Removal System	1,1,1-Trichloroethane			1.25×10^{-1}	1.25×10^{-1}
		Methyl Ethyl Ketone			1.25×10^{-1}	1.25×10^{-1}
		Methylene Chloride			1.25×10^{-1}	1.25×10^{-1}
		Carbon Tetrachloride			1.25×10^{-1}	1.25×10^{-1}
Environmental Restoration						
Tent 10	Low Temperature Thermal Desorption	Tetrachloroethylene			1.25×10^{-1}	1.25×10^{-1}
		Benzo(a)pyrene			5.00×10^{-4}	5.00×10^{-4}
Economic Development						
867-58/59	NCPP Stage 3 Operations	Beryllium			1.10×10^{-5}	1.10×10^{-5}

FUGITIVE DUST SOURCES. Particulate emissions resulting from non-point sources, such as excavating, and material transportation activities are known as fugitive dust. The activities designed to remediate the Site's contaminated soil would cause atmospheric transport of these fugitive particulate emissions. An analysis was conducted to estimate the potential air quality impacts of these fugitive dust-generating activities. While fugitive particulate emissions usually refer to total suspended particulate, health risks are of concern primarily from PM-10. For this analysis, therefore, both total suspended particulate and PM-10 emissions were considered.

The assessment of conditions under Baseline Case conditions for PM-10 and TSP were based on actual ambient monitoring data collected by CDPHE. Data from three CDPHE monitors, one on Route 128 and two on Indiana Street, were used. These samplers have been in service since July 1992. Two of the three CDPHE samplers are located to the east of the facility and are, in general, downwind of the facility. The CDPHE samplers were located based on the results of a dispersion modeling analysis of Site emission sources, and data collected at these monitors were assumed to be representative of actual fugitive dust impacts from the Site. The highest average annual and second highest 24-hour concentrations for PM-10 and total suspended particulate monitored at the CDPHE samplers were used to describe existing conditions at the Site boundary. The second highest 24-hour total suspended particulate and PM-10 concentrations were used for direct comparison to the ambient air quality standards for these pollutants which are based on highest second-high 24-hour concentration per the requirements stated in 40 CFR Part 50.6.

Monitored on-site concentrations of total suspended particulate and PM-10 were used to describe on-site concentrations for fugitive dust for Baseline Case conditions. Data from the 1993 *Site Environmental Monitoring Report* were used to reflect the worst-case year at the Site for on-site total suspended particulate and PM-10 concentrations.

For the Closure Case, PM-10 and total suspended particulate emission rates were estimated for proposed environmental restoration activities. Fugitive particulate emissions depend on many factors, including the type and duration of construction and remediation activities; soil type; moisture content; surface type (paved, unpaved); movement of transportation vehicles; and meteorological conditions such as wind speed and precipitation. In addition, control measures such as watering, covering, stabilization, and street sweeping are used to reduce fugitive emissions. Appropriate control factors were incorporated into this analysis to estimate controlled emissions for each dust-producing activity. PM-10 and total suspended particulate emissions for 24-hour and annual periods were estimated based on emission factors taken from EPA's *Compilation of Air Pollutant Emission Factors, AP-42* (EPA 1995a), *Control of Open Fugitive Dust Sources* (Cowhard 1988), and *Uncontrolled Emission Factors for Sand and Gravel Pit Operations* (CDPHE 1995d).

The estimated PM-10 and total suspended particulate emissions from anticipated construction and environmental restoration related activities for the Closure Case for the worst-case year is presented in Table B-26.

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Table B-26. Daily and Annual PM-10 and TSP Emissions for the Closure Case

Remediation Site and Operation	TSP Daily (lbs/day)	TSP Annual (tons/yr)	PM-10 Daily (lbs/day)	PM-10 Annual (tons/yr)
Plutonium Soil Excavation				
Scraping	14	1.35	9	0.94
Storage pile wind erosion	4	0.76	3	0.50
Exposed area wind erosion	9	1.66	4	0.81
Dozer/Grader operations	14	1.38	3	0.27
Trucks on the unpaved roads	148	14.79	67	6.65
Light trucks on unpaved road	9	0.88	4	0.40
Trucks on the paved roads	350	34.98	67	6.74
Light trucks on paved road	6	0.64	1	0.12
OU4 Remediation Off-Site Disposal				
Excavation	3	0.27	1	0.08
Exposed area wind erosion	2	0.32	1	0.16
Dozer/Grader operations	14	1.38	3	0.27
Trucks on unpaved road	61	6.05	27	2.72
Trucks on the paved roads	1445	144.47	278	27.83
Light trucks on paved road	6	0.64	1	0.12
Organic Chemical and Heavy Metal Contamination Sites				
Excavation	1	0.11	0.3	0.03
Storage pile wind erosion	2	0.38	1	0.25
Exposed area wind erosion	0.4	0.06	0.2	0.03
Dozer/Grader operations	7	0.69	1	0.14
Trucks on the unpaved roads	47	4.71	21	2.12
Light trucks on unpaved road	3	0.29	1	0.13
Trucks on the paved roads	336	33.62	65	6.48
Light trucks on paved road	6	0.64	1	0.12
Off-Site Waste Shipments				
Trucks on the paved roads	582	73.07	112	14.07
Generic Building Demolition				
Trucks on the paved roads	27	3.33	5	0.64

B-3.2.2 Background Sources

Based on a review of potentially significant air emissions sources in the area, two air emissions sources near the Site, the Western Aggregate, Inc. plant (located 1.5 miles north of the Site west entrance on the east side of Highway 93) and the Great Western Inorganic Chemical facility (located 2 miles west of the intersection of Indiana Street and Route 72 on the south side of the highway) were determined to be potentially significant background sources. Air emission estimates for these sources were obtained from the CDPHE APEN files. The emissions from these sources were included in the dispersion modeling analyses to obtain total pollutant concentrations at any of the receptor locations. Point source emission rates for these sources are presented in Table B-27 and are assumed to remain unchanged for Baseline Case conditions and the Closure Case.

Table B-27. Potentially Significant Background Emissions Sources in the Site Vicinity

Source Description[1]	Pollutant[2]	Hourly Emissions (lbs/hr)	Annual Emissions (tpy)
Western Aggregate Kiln Stack	SO_2	60.4	239
	NO_2	55.1	220
	Hydrogen Sulfide	3.81×10^{-3}	1.51×10^{-2}
	Methylene Chloride	2.49×10^{-2}	9.86×10^{-2}
Great Western Inorganic Main Laboratory	Nitric Acid	9.60×10^{-3}	3.80×10^{-2}
Great Western Inorganic Chromium Chloride Process	Carbon Tetrachloride	1.81×10^{-1}	7.18×10^{-1}
	Hydrochloric Acid	5.14×10^{-2}	2.04×10^{-1}
	Chlorine	9.15×10^{-2}	3.63×10^{-1}

[1]Emission rates for these sources are assumed to be the same for Baseline and Closure Cases.
[2]TSP and PM-10 emissions from these sources are not included since ambient monitoring data used to reflect background concentrations for these pollutants include impacts from these sources.

B-3.2.3 Ambient Background Concentrations

Available background ambient monitoring data were reviewed to determine its use for estimating an ambient background concentration for each pollutant selected for analysis. The ambient background levels for criteria pollutants were based primarily on the latest three years of monitoring data from CDPHE monitoring locations around the Site (CDPHE 1995f). These values are shown in Table B-28. Because there are no significant sources of hazardous air pollutants near the Site, background hazardous air pollutant levels were assumed to be zero.

Table B-28. Ambient Background Levels for Criteria Pollutants at the Site

Pollutant and Location	Averaging Time[1]	Background Concentration (ug/m^3)
NO_2, CDPHE Indiana Street Site	Annual	19
SO_2, CDPHE Welby Site	3-hour 24-hour Annual	160 40 10
CO, CDPHE Arvada Site	1-hour 8-hour	13,714 3,997
PM-10, CDPHE Indiana Street Site	24-hour Annual	32 14
TSP, CDPHE Indiana Street Site	24-hour Annual	73 31

[1]All short-term standards (i.e., ≤ 24-hour) are the second highest maximum recorded at this monitoring location. All background concentrations were obtained directly from CDPHE.

B-3.3 Nonradiological Air Quality Impacts

The air quality impacts from both existing and proposed future Site operations were estimated using the source identification and modeling procedures outline above. All modeling results were found to be below all applicable air quality standards and guideline values. The estimated impacts for on-site, off-site, and complex terrain receptors along with a comparison to applicable standards are detailed in the following sections.

B-3.3.1 On-Site Impacts

<u>POINT SOURCES.</u> Results of the on-site modeling analysis for the *CID* cases, as well as those previously estimated under Baseline Case conditions, are presented in Table B-29. On-site levels of both criteria and hazardous air pollutants are compared with occupational exposure standards set by the OSHA or the ACGIH. The estimated concentrations of each pollutant are well below the most restrictive occupational exposure limit with the exception of sulfur dioxide, nitrogen dioxide, and carbon monoxide. The primary sources of these pollutants are diesel-fired emergency generators used to supply back-up power at the Site. The combination of low stack heights, a conservative assumption that all generators were simultaneously operating at maximum capacity, and the close proximity of the sources to the receptors resulted in on-site concentrations for these combustion products that approached 50% of the occupational exposure standard.

Table B-29. Highest Estimated On-Site 8-Hour Concentrations of Criteria and Hazardous Air Pollutants Under Baseline Case Conditions and the Closure Case

Pollutant	Maximum 8-Hour Concentrations[1] (ug/m^3)		Occupational Exposure Standards[2]	Percent of the Standard	
	Baseline Case	Closure Case	(ug/m^3)	Baseline Case	Closure Case
Criteria Pollutants[3]					
Carbon Monoxide	5,005	5,005	40,000	13	13
Lead	1.70×10^{-10}	1.70×10^{-10}	50	< 1	< 1
Nitrogen Dioxide[4]	2,424	2,426	5,600	43	43
Sulfur Dioxide	2,308	2,308	5,000	46	46
Hazardous Pollutants					
Ammonia[5]	35.8	35.8	17,000	< 1	< 1
Benzo(a)pyrene[6]	–	3.0×10^{-2}	200	–	< 1
Beryllium	4.0×10^{-3}	7.0×10^{-3}	2.0	< 1	< 1
Carbon Tetrachloride	9.3	22.7	12,600	< 1	< 1
Nitric Acid	33.4	33.4	5,000	1	1
Chlorine	12.3	12.3	1,500	1	1
Chloroform	5.6	5.6	9,780	< 1	< 1
Dioctyl Phthalate	0.7	0.7	5,000	< 1	< 1
Hydrochloric Acid	5.1	5.1	7,000	< 1	< 1
Hydrofluoric Acid	2.6	2.6	2,500	< 1	< 1
Hydrogen Sulfide	98.0	98.0	14,000	1	1
Methyl Ethyl Ketone	–	13.3	590,000	–	< 1
Methylene Chloride	9.5	22.8	1,765,000	< 1	< 1
Tetrachloroethylene	–	8.7	689,000	–	< 1
1,1,1-Trichloroethane	3,657	3,657	1,900,000	< 1	< 1

[1]The values presented are the highest estimated 8-hour concentration for on-site receptors.
[2]All occupational exposure values represent OSHA standards, unless otherwise specified.
[3]On-site PM-10 and TSP concentrations for Baseline and Closure Cases are presented in Table B-30.
[4]It was assumed that 20% of oxides of nitrogen emissions from stacks are nitrogen dioxide. This is a conservative assumption that is based on the fact that less than 10% of nitrogen oxide emissions from combustion sources are in the form of nitrogen dioxide (Janssen 1988).
[5]Threshold Limit Value established by the ACGIH.
[6]Threshold Limit Value established by the ACGIH for Polycyclic Aromatic Hydrocarbons was applied to benzo(a)pyrene.

FUGITIVE DUST SOURCES. Predicted on-site 8-hour concentrations (i.e., Baseline Case concentrations plus impacts from environmental restoration and construction activities) were compared with the appropriate OSHA standards for PM-10 and total suspended particulate. The ambient monitoring data for the Baseline Case conditions along with the modeling results for the Closure Case are presented in Table B-30. The on-site PM-10 and total suspended particulate concentrations are below the applicable occupational health standards. The impacts for the Closure Case are significantly higher than for the Baseline Case conditions due to environmental restorations activities such as excavation, equipment operation, and transportation of material on unpaved roads.

Table B-30. 8-Hour PM-10 and TSP Concentrations at On-Site Receptors

Pollutant	Maximum 8-hr Concentrations[1] (ug/m^3)		Occupational Exposure Standards[2]	Percent of the Standard	
	Baseline Case	Closure Case	(ug/m^3)	Baseline Case	Closure Case
PM-10	90.8	284.7	5,000	2	6
TSP	157.5	987.4	15,000	1	7

[1]Developed from monitored and modeled 24-hour values using persistence factor of 1.75 as described in Section B-3.1.1.
[2]PM-10 and total suspended particulate emissions were not modeled for Baseline Case conditions. It was assumed that PM-10 and TSP concentrations obtained from on-site co-located monitors are representative of on-site conditions for the Baseline Case conditions. Data represent 24-hour maximum on-site concentrations from the 1993 *Site Environmental Monitoring Report* (DOE 1994i) that were adjusted to reflect 8-hour concentrations using a persistence factor of 1.75.

B-3.3.2 Off-Site Impacts

POINT SOURCES. Results of the off-site modeling analysis for criteria pollutants from point sources are presented in Table B-31 for Baseline Case conditions. Modeling results for the Closure Case are shown in Table B-32. These tables include impacts from the Site and other nearby sources, ambient background concentrations, and total concentrations for sulfur dioxide, nitrogen dioxide, carbon dioxide, and lead. Off-site concentrations for the remaining two criteria pollutants, PM-10 and total suspended particulate, are presented in the following section for fugitive dust sources. The highest off-site impacts are found at receptors located along or in close proximity to the Site boundary. The estimated total off-site concentrations for these criteria pollutants under Baseline Case conditions and the Closure Case were all below National Ambient Air Quality Standards and State of Colorado air quality standards.

Results of the off-site modeling analysis for hazardous pollutants from point sources for Baseline Case conditions and the Closure Case are presented in Tables B-33 and B-34, respectively. These tables include impacts from the Site and other nearby sources along with total concentrations for hazardous pollutants at receptors off-site and in nearby towns. The estimated total off-site concentrations of hazardous air pollutants from Site activities are compared with recommended guidelines values specifically developed for this analysis using standards and guidelines from 12 different states, as discussed in Section B-3.1.2 of this Appendix. Maximum off-site concentrations of all hazardous air pollutants considered were found to be below the recommended values.

Table B-31. Total Estimated Off-Site Concentrations of Criteria Pollutants for Baseline Case Conditions

Pollutant	Avg. Time	Site Impacts		Background Sources Impacts[2]		Background Levels[3]	Total Concentrations		NAAQS[4]	Percent of NAAQS		State Ambient Standard[5]	Percent of State Standards	
		Off-Site Receptors	Nearby Towns[1]	Off-Site Receptors	Nearby Towns		Off-Site Receptors	Nearby Towns		Off-Site Receptors	Nearby Towns		Off-Site Receptors	Nearby Towns
		(ug/m^3)	(ug/m^3)	(ug/m^3)	(ug/m^3)	(ug/m^3)	(ug/m^3)	(ug/m^3)	(ug/m^3)	(%)	(%)	(ug/m^3)	(%)	(%)
Sulfur Dioxide	3-hr	269.5	133.7	18.5	7.1	160.0	448.0	300.8	1,300	34	23	700	64	43
	24-hr	91.2	19.0	6.1	1.3	40.0	137.3	60.3	365	38	17			
	Annual	0.1	0.02	0.7	0.1	10.0	10.8	10.1	80	14	13			
Nitrogen Dioxide[6]	Annual	1.4	0.2	0.7	0.1	19.0	21.1	19.3	100	21	19			
Carbon Monoxide	1-hr	1159.2	271.7	–	–	13,714	14,873	13,986	40,000	37	35			
	8-hr	303.8	60.2	–	–	3,997	4,301	4,057	10,000	43	41			
Lead	Monthly	4.8×10^{-14}	4.8×10^{-15}	–	–	–	4.8×10^{-14}	4.8×10^{-15}				1.5	< 1	< 1

[1]The values presented are the estimated highest concentrations for off-site receptors at or near Site boundary.
[2]Background sources impacts are from potentially significant emission sources outside the Site and include emissions from the Western Aggregate Inc. and the Great Western Inorganic Chemical facility.
[3]Background pollutant levels are based on the 1992-1994 monitoring data obtained from CDPHE.
[4]NAAQS are National Ambient Air Quality Standards.
[5]State Ambient Standards are Colorado State Ambient Air Quality Standards.
[6]It was conservatively assumed that *100% of oxides of nitrogen emissions from stacks are nitrogen dioxide*. Even though only a small percentage of nitrogen oxide emissions from combustion sources are in the form of nitrogen dioxide, nitrogen oxides convert to nitrogen dioxide in the atmosphere over time, and it will take time for Site emissions to reach off-site receptors.

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Table B-32. Total Estimated Off-Site Concentrations of Criteria Pollutants for the Closure Case

Pollutant	Avg. Time	Site Impacts		Background Sources Impacts[2]		Background Levels[3]	Total Concentrations		NAAQS[4]	Percent of NAAQS		State Ambient Standard[5]	Percent of State Standards	
		Off-Site Receptors	Nearby Towns[1]	Off-Site Receptors	Nearby Towns		Off-Site Receptors	Nearby Towns		Off-Site Receptors	Nearby Towns		Off-Site Receptors	Nearby Towns
		(ug/m^3)	(ug/m^3)	(ug/m^3)	(ug/m^3)	(ug/m^3)	(ug/m^3)	(ug/m^3)	(ug/m^3)	(%)	(%)	(ug/m^3)	(%)	(%)
Sulfur	3-hr	269.5	133.8	18.5	7.1	160.0	448.0	300.9	1,300	34	23	700	64	43
Dioxide	24-hr	91.2	19.2	6.1	1.3	40.0	137.3	60.5	365	38	17			
	Annual	0.2	0.02	0.7	0.1	10.0	10.8	10.1	80	14	13			
Nitrogen Dioxide[6]	Annual	1.5	0.2	0.7	0.1	19.0	21.2	19.3	100	21	19			
Carbon	1-hr	1159.2	272.6	–	–	13,714	14,873	13,987	40,000	37	35			
Monoxide	8-hr	304.0	60.4	–	–	3,997	4,301	4,057	10,000	43	41			
Lead	Monthly	4.8×10^{-14}	4.8×10^{-15}	–	–	–	4.8×10^{-14}	4.8×10^{-15}				1.5	< 1	< 1

[1]The values presented are the estimated highest concentrations for off-site receptors at or near Site boundary.
[2]Background sources impacts are from potentially significant emission sources outside the Site and include emissions from the Western Aggregate Inc. and the Great Western Inorganic Chemical facility.
[3]Background pollutant levels are based on the 1992-1994 monitoring data obtained from CDPHE.
[4]NAAQS are National Ambient Air Quality Standards.
[5]State Ambient Standards are Colorado State Ambient Air Quality Standards.
[6]It was conservatively assumed that 100% of oxides of nitrogen emissions from stacks are nitrogen dioxide. Even though only a small percentage of nitrogen oxide emissions from combustion sources are in the form of nitrogen dioxide, nitrogen oxides convert to nitrogen dioxide in the atmosphere over time, and it will take time for Site emissions to reach off-site receptors.

Table B-33. Total Estimated Off-Site Concentrations of Hazardous Air Pollutants for Baseline Case Conditions

Pollutant	Average Time	Site Impacts		Background Sources Impacts[2]		Total Concentrations[3]			Percent of Recommended Values	
		Off-Site Receptors	Nearby Towns[1]	Off-Site Receptors	Nearby Towns	Off-Site Receptors	Nearby Towns	Recommended Values[4]	Off-Site Receptors	Nearby Towns
		(ug/m^3)	(ug/m^3)	(ug/m^3)	(ug/m^3)	(ug/m^3)	(ug/m^3)	(ug/m^3)	(%)	(%)
Ammonia	1-hr 8-hr 24-hr Annual	7.1 1.6 0.6 8.8×10^{-3}	1.4 0.2 0.1 1.1×10^{-3}	– – – –	– – – –	7.1 1.6 0.6 8.8×10^{-3}	1.4 0.2 0.1 1.1×10^{-3}	1,800 170 4.73 4.73	< 1 1 12 < 1	< 1 < 1 1 < 1
Beryllium	1-hr 8-hr 24-hr Annual	4.6×10^{-4} 5.8×10^{-5} 1.9×10^{-5} 6.0×10^{-8}	1.0×10^{-4} 1.3×10^{-5} 4.0×10^{-6} 1.0×10^{-8}	– – – –	– – – –	4.6×10^{-4} 5.8×10^{-5} 1.9×10^{-5} 6.0×10^{-8}	1.0×10^{-4} 1.3×10^{-5} 4.0×10^{-6} 1.0×10^{-8}	0.05 0.01 0.001 0.0004	1 1 2 < 1	< 1 < 1 < 1 < 1
Carbon Tetrachloride	1-hr 8-hr 24-hr Annual	1.5 0.3 0.1 2.4×10^{-3}	0.2 0.04 0.02 2.9×10^{-4}	7.8 1.2 0.4 7.8×10^{-3}	1.2 0.2 0.1 7.5×10^{-4}	9.3 1.5 0.5 1.0×10^{-2}	1.4 0.2 0.1 1.0×10^{-3}	1,300 300 74.4 0.07	1 < 1 1 15	< 1 < 1 < 1 1
Chlorine	1-hr 8-hr 24-hr Annual	4.4 0.6 0.2 2.4×10^{-3}	0.6 0.1 0.02 2.3×10^{-4}	3.9 0.6 0.2 3.9×10^{-3}	0.8 0.1 0.03 4.0×10^{-4}	8.4 1.2 0.4 6.3×10^{-3}	1.3 0.2 0.1 6.3×10^{-4}	300 15 3.6 0.4	3 8 11 2	< 1 1 1 < 1
Chloroform	1-hr 8-hr 24-hr Annual	3.6 0.9 0.3 2.9×10^{-3}	0.7 0.1 0.04 5.0×10^{-4}	– – – –	– – – –	3.6 0.9 0.3 2.9×10^{-3}	0.7 0.1 0.04 5.0×10^{-4}	980 250 117.6 0.04	< 1 < 1 < 1 7	< 1 < 1 < 1 1
Dioctyl Phthalate	1-hr 8-hr 24-hr Annual	0.3 0.1 0.02 2.0×10^{-4}	0.03 0.01 0.002 2.0×10^{-5}	– – – –	– – – –	0.3 0.06 0.02 2.0×10^{-4}	0.03 0.01 0.002 2.0×10^{-5}	1,200 – – 12	< 1 – – < 1	< 1 – – < 1
Hydrochloric Acid	1-hr 8-hr 24-hr Annual	2.8 0.4 0.1 3.1×10^{-3}	0.3 0.1 0.02 3.8×10^{-4}	2.2 0.3 0.1 2.2×10^{-3}	0.4 0.1 0.02 2.0×10^{-4}	5.0 0.7 0.2 5.3×10^{-3}	0.7 0.1 0.04 5.8×10^{-4}	150 75 2.03 2.03	3 1 12 < 1	< 1 < 1 2 < 1
Hydrofluoric Acid	1-hr 8-hr 24-hr Annual	1.0 0.1 0.1 1.3×10^{-3}	0.1 0.02 0.01 1.0×10^{-4}	– – – –	– – – –	1.0 0.1 0.1 1.3×10^{-3}	0.1 0.02 0.01 1.0×10^{-4}	26 26 0.68 0.34	4 1 8 < 1	< 1 < 1 1 < 1
Hydrogen Sulfide	1-hr 8-hr 24-hr Annual	35.4 4.4 1.5 1.9×10^{-2}	4.6 0.6 0.2 1.9×10^{-3}	2.5×10^{-3} 7.0×10^{-4} 4.0×10^{-4} 4.0×10^{-5}	1.0×10^{-3} 2.0×10^{-4} 8.0×10^{-5} 1.0×10^{-5}	35.4 4.4 1.5 1.9×10^{-2}	4.6 0.6 0.2 1.9×10^{-3}	142 140 3.79 0.9	25 3 39 2	3 < 1 5 < 1

Methylene Chloride	1-hr 8-hr 24-hr Annual	2.2 0.5 0.2 3.9×10^{-3}	0.5 0.1 0.03 6.4×10^{-4}	1.6×10^{-2} 4.0×10^{-3} 3.0×10^{-3} 2.7×10^{-4}	9.0×10^{-3} 1.0×10^{-3} 5.0×10^{-4} 4.0×10^{-5}	2.2 0.5 0.2 4.2×10^{-3}	0.5 0.1 0.03 6.8×10^{-4}	260 1,740 417.6 2	1 < 1 < 1 < 1	< 1 < 1 < 1 < 1
Nitric Acid	1-hr 8-hr 24-hr Annual	21.7 3.0 1.1 2.8×10^{-2}	2.1 0.4 0.1 2.9×10^{-3}	0.4 0.1 0.02 3.7×10^{-4}	0.1 0.01 0.003 4.0×10^{-5}	22.1 3.1 1.1 2.8×10^{-2}	2.2 0.4 0.2 2.9×10^{-3}	500 100 50 0.12	4 3 2 24	< 1 < 1 < 1 2
1,1,1,-Trichloroethane	1-hr 8-hr 24-hr Annual	414.2 52.1 17.4 2.1×10^{-2}	108.4 13.6 4.5 2.0×10^{-3}	– – – –	– – – –	414.2 52.1 17.4 2.1×10^{-2}	108.4 13.6 4.5 2.0×10^{-3}	190,000 38,000 1,040 1,000	< 1 < 1 2 < 1	< 1 < 1 < 1 < 1

[1]The values presented are the highest estimated concentrations for off-site receptors at or near Site boundary and nearby towns.
[2]Background source impacts are from potentially significant emission sources outside the Site and include emissions from the Western Aggregate Inc. and the Great Western Inorganic Chemical facility.
[3]Total estimated concentrations of each pollutant include background levels.
[4]Recommended values are the air quality guidelines, values, or standards for hazardous air pollutants developed by different states, as discussed in Section B-3.1.2.

Table B-34. Total Estimated Off-Site Concentrations of Hazardous Air Pollutants for the Closure Case

Pollutant	Average Time	Site Impacts		Background Sources Impacts[2]		Total Concentrations[3]		Recommended Values[4]	Percent of Recommended Values	
		Off-Site Receptors	Nearby Towns[1]	Off-Site Receptors	Nearby Towns	Off-Site Receptors	Nearby Towns		Off-Site Receptors	Nearby Towns
		($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)	($\mu g/m^3$)	(%)	(%)
Ammonia	1-hr	7.1	1.4	–	–	7.1	1.4	1,800	< 1	< 1
	8-hr	1.6	0.2	–	–	1.6	0.2	170	1	< 1
	24-hr	0.6	0.1	–	–	0.6	0.1	4.73	12	1
	Annual	8.8×10^{-3}	1.1×10^{-3}	–	–	8.8×10^{-3}	1.1×10^{-3}	4.73	< 1	< 1
Benzo(a)pyrene	1-hr	0.01	1.4×10^{-3}	–	–	0.01	1.4×10^{-3}	0.79	1	< 1
	8-hr	0.002	2.0×10^{-4}	–	–	0.002	2.0×10^{-4}	0.006	33	3
	24-hr	6.0×10^{-4}	6.0×10^{-5}	–	–	6.0×10^{-4}	6.0×10^{-5}	0.006	10	1
	Annual	8.0×10^{-6}	1.0×10^{-6}	–	–	8.0×10^{-6}	1.0×10^{-6}	0.0003	3	< 1
Beryllium	1-hr	4.6×10^{-4}	1.0×10^{-4}	–	–	4.6×10^{-4}	1.0×10^{-4}	0.05	1	< 1
	8-hr	8.1×10^{-5}	1.3×10^{-5}	–	–	8.1×10^{-5}	1.3×10^{-5}	0.01	1	< 1
	24-hr	2.5×10^{-5}	4.0×10^{-6}	–	–	2.5×10^{-5}	4.0×10^{-6}	0.001	3	< 1
	Annual	2.4×10^{-7}	2.0×10^{-8}	–	–	2.4×10^{-7}	2.0×10^{-8}	0.0004	< 1	< 1
Carbon Tetrachloride	1-hr	3.6	0.5	7.8	1.2	11.4	1.7	1,300	1	< 1
	8-hr	0.6	0.1	1.2	0.2	1.8	0.3	300	1	< 1
	24-hr	0.2	0.0	0.4	0.1	0.6	0.1	74.4	1	< 1
	Annual	4.1×10^{-3}	4.9×10^{-4}	7.8×10^{-3}	7.5×10^{-4}	1.2×10^{-2}	1.2×10^{-3}	0.07	17	2
Chlorine	1-hr	4.4	0.6	3.9	0.8	8.4	1.3	300	3	< 1
	8-hr	0.6	0.1	0.6	0.1	1.2	0.2	15	8	1
	24-hr	0.2	0.02	0.2	0.03	0.4	0.1	3.6	11	1
	Annual	2.4×10^{-3}	2.3×10^{-4}	3.9×10^{-3}	4.0×10^{-4}	6.3×10^{-3}	6.3×10^{-4}	0.4	2	< 1
Chloroform	1-hr	3.6	0.7	–	–	3.6	0.7	980	< 1	< 1
	8-hr	0.9	0.1	–	–	0.9	0.1	250	< 1	< 1
	24-hr	0.3	0.04	–	–	0.3	0.04	117.6	< 1	< 1
	Annual	2.9×10^{-3}	5.0×10^{-4}	–	–	2.9×10^{-3}	5.0×10^{-4}	0.04	7	1
Dioctyl Phthalate	1-hr	0.3	0.03	–	–	0.3	0.03	1,200	< 1	< 1
	8-hr	0.1	0.01	–	–	0.1	0.01	–	–	–
	24-hr	0.02	0.002	–	–	0.02	0.002	–	–	–
	Annual	2.0×10^{-4}	2.0×10^{-5}	–	–	2.0×10^{-4}	2.0×10^{-5}	12	< 1	< 1
Hydrochloric Acid	1-hr	2.9	0.4	2.2	0.4	5.1	0.9	150	3	1
	8-hr	0.4	0.1	0.3	0.1	0.8	0.1	75	1	< 1
	24-hr	0.2	0.03	0.1	0.02	0.3	0.05	2.03	13	2
	Annual	4.0×10^{-3}	6.2×10^{-4}	2.2×10^{-3}	2.0×10^{-4}	6.2×10^{-3}	8.2×10^{-4}	2.03	< 1	< 1
Hydrofluoric Acid	1-hr	1.0	0.1	–	–	1.0	0.1	26	4	< 1
	8-hr	0.1	0.02	–	–	0.1	0.02	26	1	< 1
	24-hr	0.1	0.01	–	–	0.1	0.01	0.68	8	1
	Annual	1.3×10^{-3}	1.0×10^{-4}	–	–	1.3×10^{-3}	1.0×10^{-4}	0.34	< 1	< 1

Hydrogen Sulfide	1-hr	35.4	4.6	2.5×10^{-3}	1.0×10^{-3}	35.4	4.6	142	25	3
	8-hr	4.4	0.6	7.0×10^{-4}	2.0×10^{-4}	4.4	0.6	140	3	< 1
	24-hr	1.5	0.2	4.0×10^{-4}	8.0×10^{-5}	1.5	0.2	3.79	39	5
	Annual	1.9×10^{-2}	1.9×10^{-3}	4.0×10^{-5}	1.0×10^{-5}	1.9×10^{-2}	1.9×10^{-3}	0.9	2	< 1
Methyl Ethyl Ketone	1-hr	2.1	0.3	–	–	2.1	0.3	88,500	< 1	< 1
	8-hr	0.4	0.1	–	–	0.4	0.1	2,350	< 1	< 1
	24-hr	0.1	0.02	–	–	0.1	0.02	360	< 1	< 1
	Annual	1.7×10^{-3}	2.0×10^{-4}	–	–	1.7×10^{-3}	2.0×10^{-4}	32.07	< 1	< 1
Methylene Chloride	1-hr	4.0	0.7	1.6×10^{-2}	9.0×10^{-3}	4.0	0.7	260	2	< 1
	8-hr	0.7	0.2	4.0×10^{-3}	1.0×10^{-3}	0.7	0.2	1,740	< 1	< 1
	24-hr	0.2	0.1	3.0×10^{-3}	5.0×10^{-4}	0.2	0.1	417.6	< 1	< 1
	Annual	5.5×10^{-3}	8.4×10^{-4}	2.7×10^{-4}	4.0×10^{-5}	5.8×10^{-3}	8.8×10^{-4}	2	< 1	< 1
Nitric Acid	1-hr	21.7	2.3	0.4	0.1	22.1	2.4	500	4	< 1
	8-hr	3.0	0.5	0.1	0.01	3.1	0.5	100	3	< 1
	24-hr	1.1	0.1	0.0	0.003	1.1	0.2	50	2	< 1
	Annual	2.9×10^{-2}	3.1×10^{-3}	3.7×10^{-4}	4.0×10^{-5}	2.9×10^{-2}	3.1×10^{-3}	0.12	24	3
Tetrachloroethylene	1-hr	2.5	0.4	–	–	2.5	0.4	11,000	< 1	< 1
	8-hr	0.5	0.05	–	–	0.5	0.05	1,700	< 1	< 1
	24-hr	0.2	0.02	–	–	0.2	0.02	770	< 1	< 1
	Annual	2.1×10^{-3}	2.3×10^{-4}	–	–	2.1×10^{-3}	2.3×10^{-4}	0.01	21	2
1,1,1,-Trichloroethane	1-hr	414.2	108.4	–	–	414.2	108.4	190,000	< 1	< 1
	8-hr	52.1	13.6	–	–	52.1	13.6	38,000	< 1	< 1
	24-hr	17.4	4.5	–	–	17.4	4.5	1,040	2	< 1
	Annual	2.3×10^{-2}	2.2×10^{-3}	–	–	2.3×10^{-2}	2.2×10^{-3}	1,000	< 1	< 1

[1]The values presented are the highest estimated concentrations for off-site receptors at or near Site boundary and nearby towns.
[2]Background source impacts are from potentially significant emission sources outside the Site and include emissions from the Western Aggregate Inc. and the Great Western Inorganic Chemical facility.
[3]Total estimated concentrations of each pollutant include background levels.
[4]Recommended values are the air quality guidelines, values, or standards for hazardous air pollutants developed by different states, as discussed in Section B-3.1.2.

FUGITIVE DUST SOURCES. Predicted off-site 24-hour and annual concentrations were compared with the NAAQS for PM-10 and State of Colorado standards for total suspended particulate. The results presented in Table B-35 for Baseline Case conditions and the Closure Case show that the total predicted concentrations of both PM-10 and total suspended particulate are below appropriate standards. All maximum concentrations for total suspended particulate and PM-10 are found at receptors located on or in close proximity to the Site boundary.

Table B-35. 24-Hour and Annual PM-10 and TSP Concentrations at Off-Site Receptors

Pollutant	Average Time	Total Concentrations (ug/m^3)[1]		Ambient Standard (ug/m^3)[3]	Percent of the Standard	
		Baseline Case	Closure Case		Baseline Case	Closure Case
PM-10	24-hr	32.0	37.5	150	21	25
	Annual	14.0	22.4	50	28	45
TSP	24-hr	73.0	86.3	260	28	33
	Annual	31.0	41.8	75	41	56

[1]Total concentrations include Baseline Case levels plus impacts from environmental restoration measures for the Closure Case.
[2]The off-site fugitive dust impacts for Baseline Case conditions are assumed to be the second highest 24-hour and highest annual monitored concentrations recorded by the CDPHE ambient total suspended particulate and PM-10 monitors located on the eastern boundary of the Site.
[3]The NAAQS standard is shown for PM-10 while the State of Colorado standard is shown for total suspended particulate. The 24-hour total suspended particulate and PM-10 standards are compared to the second highest monitored or modeled concentration per the requirements in 40 CFR Part 50.6.

B-3.3.3 Complex Terrain Impacts

The 24-hour complex terrain modeling results indicate that there are two locations where maximum impacts are predicted to occur. For the emissions released predominantly from the heating plant stacks (i.e., the criteria pollutants), the maximum elevated terrain receptor is located approximately 4 kilometers from the emission sources on an unnamed hill at an elevation of 80 meters above the base elevation of the emission sources. For the pollutants released from lower stacks (i.e., the hazardous air pollutants), the maximum elevated terrain receptor is located at the western edge of the Site boundary at an elevation of 30 meters above the base elevation of the emission sources. For both of these source types, estimated impacts decrease with increasing distance from the Site because the additional plume dispersion caused by the increased distance is greater than the effects caused by taller receptor heights.

The maximum 24-hour value for each pollutant under Baseline Case conditions was converted into 1-hour, 3-hour, 8-hour, and annual values following the procedures previously discussed. Pollutant levels for the Closure Case were estimated by establishing a multiplier applied to the estimated Baseline Case concentrations for each pollutant. These results, shown in Table B-36 for criteria pollutants and Table B-37 for hazardous air pollutants, were then compared with the appropriate air quality standards and guidelines discussed in Section B-3.1.2 of this Appendix. As can be seen from these results, the air quality impacts from the Site emissions on elevated terrain receptors are well below appropriate standards and recommended values.

Table B-36. Highest Estimated Impact of Criteria Pollutants on Complex Terrain Receptors for Baseline Case Conditions and the Closure Case

Pollutant	Average Time	Total Concentrations (ug/m^3)[1]		Ambient Standard (ug/m^3)[2]	Percent of the Standard	
		Baseline Case	Closure Case		Baseline Case	Closure Case
Sulfur Dioxide	3-hr 24-hr Annual	342.1 95.0 0.1	342.6 95.2 0.1	700 365 80	49 26 < 1	49 26 < 1
Nitrogen Dioxide	Annual	1.2	1.2	100	1	1
Carbon Monoxide	1-hr 8-hr	136.4 95.5	136.9 95.9	40,000 10,000	< 1 1	< 1 1
Lead[3]	Monthly	4.8×10^{-15}	4.8×10^{-15}	1.5	< 1	< 1

[1]Maximum hourly emissions were used to estimate short-term (1-hour, 3-hour, and 24-hour) impacts while maximum annual emissions were used to estimate annual impacts.

[2]All standards are National Ambient Air Quality Standards with the exception of the 3-hour standard for SO_2, which is a State of Colorado standard.

[3]The predicted 1-hour lead impact is conservatively compared to the monthly State of Colorado standard for lead.

Table B-37. Highest Estimated Impact of Hazardous Air Pollutants on Complex Terrain Receptors for Baseline Case Conditions and the Closure Case

Pollutant	Average Time	Total Concentrations (ug/m³)[1] Baseline Case	Total Concentrations (ug/m³)[1] Closure Case	Recommended Value (ug/m³)[2]	Percent of the Recommended Value Baseline Case	Percent of the Recommended Value Closure Case
Ammonia	1-hr 8-hr 24-hr Annual	8.4×10^{-1} 5.9×10^{-1} 2.1×10^{-1} 7.4×10^{-3}	8.4×10^{-1} 5.9×10^{-1} 2.1×10^{-1} 7.4×10^{-3}	1,800 170 4.73 4.73	< 1 < 1 4 < 1	< 1 < 1 4 < 1
Benzo(a)pyrene	1-hr 8-hr 24-hr Annual	– – – –	5.9×10^{-4} 4.1×10^{-4} 1.5×10^{-4} 5.2×10^{-6}	0.79 0.006 0.006 0.0003	– – – –	< 1 7 2 2
Beryllium	1-hr 8-hr 24-hr Annual	1.0×10^{-6} 7.3×10^{-7} 2.6×10^{-7} 9.1×10^{-9}	4.1×10^{-6} 2.8×10^{-6} 1.0×10^{-6} 3.6×10^{-8}	0.05 0.01 0.001 0.0004	< 1 < 1 < 1 < 1	< 1 1 1 < 1
Carbon Tetrachloride	1-hr 8-hr 24-hr Annual	1.0×10^{-1} 7.2×10^{-2} 2.6×10^{-2} 1.9×10^{-3}	2.5×10^{-1} 1.7×10^{-1} 6.2×10^{-2} 3.2×10^{-3}	1,300 300 74.4 0.07	< 1 < 1 < 1 3	< 1 < 1 < 1 5
Chlorine	1-hr 8-hr 24-hr Annual	3.0×10^{-2} 2.1×10^{-2} 7.4×10^{-3} 1.1×10^{-3}	3.0×10^{-2} 2.1×10^{-2} 7.4×10^{-3} 1.1×10^{-3}	300 15 3.6 0.4	< 1 < 1 < 1 < 1	< 1 < 1 < 1 < 1
Chloroform	1-hr 8-hr 24-hr Annual	4.2×10^{-1} 2.9×10^{-1} 1.0×10^{-1} 3.7×10^{-3}	4.2×10^{-1} 2.9×10^{-1} 1.0×10^{-1} 3.7×10^{-3}	980 250 117.6 0.04	< 1 < 1 < 1 9	< 1 < 1 < 1 9
Dioctyl Phthalate	1-hr 8-hr 24-hr Annual	1.4×10^{-2} – – 1.2×10^{-4}	1.4×10^{-2} – – 1.2×10^{-4}	1,200 – – 12	< 1 – – < 1	< 1 – – < 1
Hydrochloric Acid	1-hr 8-hr 24-hr Annual	2.0×10^{-1} 1.4×10^{-1} 5.1×10^{-2} 2.8×10^{-3}	5.0×10^{-1} 3.5×10^{-1} 1.3×10^{-1} 1.5×10^{-2}	150 75 2.03 2.03	< 1 < 1 2 < 1	< 1 < 1 6 < 1
Hydrofluoric Acid	1-hr 8-hr 24-hr Annual	6.1×10^{-2} 4.3×10^{-3} 1.5×10^{-3} 1.0×10^{-4}	6.1×10^{-2} 4.3×10^{-3} 1.5×10^{-3} 1.0×10^{-4}	26 26 0.68 0.34	< 1 < 1 < 1 < 1	< 1 < 1 < 1 < 1
Hydrogen Sulfide	1-hr 8-hr 24-hr Annual	3.1×10^{-1} 2.1×10^{-1} 7.6×10^{-2} 1.1×10^{-2}	3.1×10^{-1} 2.1×10^{-1} 7.6×10^{-2} 1.1×10^{-2}	142 140 3.79 0.90	< 1 < 1 2 1	< 1 < 1 2 1
Methyl Ethyl Ketone	1-hr 8-hr 24-hr Annual	– – – –	1.5×10^{-1} 1.0×10^{-1} 3.7×10^{-2} 1.3×10^{-3}	88,500 2,350 360 32.07	– – – –	< 1 < 1 < 1 < 1
Methylene Chloride	1-hr 8-hr 24-hr Annual	4.3×10^{-1} 3.0×10^{-1} 1.1×10^{-1} 4.8×10^{-3}	5.7×10^{-1} 4.0×10^{-1} 1.4×10^{-1} 6.0×10^{-3}	35,000 1,740 417.6 0.24	< 1 < 1 < 1 2	< 1 < 1 < 1 3

Nitric Acid	1-hr 8-hr 24-hr Annual	1.3 9.4×10^{-1} 3.4×10^{-1} 2.2×10^{-2}	1.5 1.0 3.7×10^{-1} 2.3×10^{-2}	500 100 50 0.12	< 1 1 1 18	< 1 1 1 19
Tetrachloroethylene	1-hr 8-hr 24-hr Annual	– – – –	1.5×10^{-1} 1.1×10^{-1} 3.7×10^{-2} 1.3×10^{-3}	11,000 1,700 770 0.01	– – – –	< 1 < 1 < 1 13
1,1,1-Trichloroethane	1-hr 8-hr 24-hr Annual	5.8 4.1 1.5 1.3×10^{-2}	6.0 4.2 1.5 1.4×10^{-2}	190,000 38,000 1,040 1,000	< 1 < 1 < 1 < 1	< 1 < 1 < 1 < 1

[1]Maximum hourly emissions were used to estimate short-term (1-hour, 3-hour, and 24-hour) impacts while maximum annual emissions were used to estimate annual impacts.

[2]Recommended Values are the air quality guidelines, values, or standards for hazardous air pollutants developed by different states, as discussed in Section B-3.1.2.

B-3.4 Nonradiological Human Health Impact Analysis

The purpose of the nonradiological public human health risk assessment is to evaluate the potential for adverse human health impacts from the release of pollutants from the Site for the Baseline Case period and the Closure Case. Differences in risk between the two were compared. The assessment was conducted in accordance with EPA risk assessment guidance document, *Risk Assessment Guidance for Superfund, Volume I, Human Health Evaluation Manual* (EPA 1989a). The major components included are data evaluation, toxicity assessment, exposure assessment, and risk characterization as shown in Figure B-3. Data evaluation defines inputs to the risk analysis. This step establishes the limitations of the assessment because predictions of risk can only be as precise as the input data. Toxicity assessment involves chemical-specific information on potential health effects related to intake and reflects much of the uncertainty of the risk assessment which is in the area of dose response. The exposure assessment examines the possible scenarios and defines potential exposure pathways, potentially exposed populations, chemicals of concern, and intake parameters. Risk characterization applies the conceptual model for exposure to the toxicity assessment to quantitatively estimate risk. Health risks are quantified, and uncertainties and limitations of these values are discussed.

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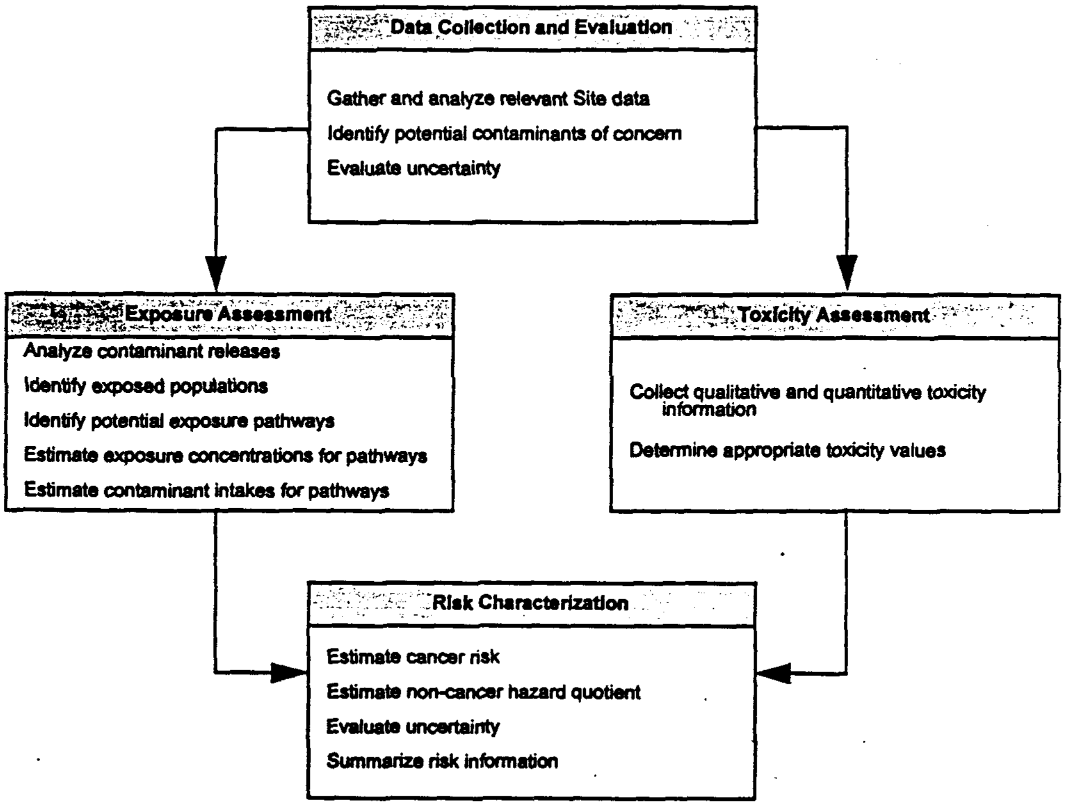
Figure B-3. Human Health Risk Assessment



In order for health impacts to actually occur, there must be a mechanism of release, a sufficient quantity of release, a pathway between the source of the release and the receptor population, and a mechanism of chemical intake by the receptor population. For purposes of the SWEIS, the entire Site is considered the source area. Therefore, individual release sources within the Site boundary were examined collectively and total releases to the environment were quantified and evaluated for possible human health impacts. As a conservative measure, maximum potential exposures were modeled. These maximum exposures do not actually occur from the Site. However, by modeling a hypothetical bounding scenario, a bounding maximum possible risk from the Site was determined. The hypothetical bounding scenario estimates exposure to an individual that comes into contact with the highest predicted concentrations of contaminants simultaneously on a chronic (long-term) basis. Exposure scenarios of lesser duration or of lower concentrations and lower intake rates are assumed to be less. If there is no risk to human health under the bounding exposure scenario then it can be assumed that actual Site conditions are even less likely to pose a risk to human health.

Based on the SWEIS alternatives, environmental data were selected to best delineate Site-wide impacts to the off-site public and on-site workers. Surface water, ground water, and air emissions were considered possible source terms for the Site. Data screening techniques used for surface and ground water are included in Appendix D. Air quality data and the modeling techniques used to estimate ambient air concentrations are contained in Appendix H.

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In order for health impacts to actually occur, there must be a mechanism of release, a sufficient quantity of release, a pathway between the source of the release and the receptor population, and a mechanism of chemical intake by the receptor population. For purposes of this assessment, the entire Site is considered the source area. Therefore, individual release sources within the Site boundary were examined collectively and total releases to the environment were quantified and evaluated for possible human health impacts. As a conservative measure, maximum potential exposures were modeled. These maximum exposures do not actually occur from the Site. However, by modeling a hypothetical bounding scenario, a bounding maximum possible risk from the Site was determined. The hypothetical bounding scenario estimates exposure to an individual that comes into contact with the highest predicted concentrations of contaminants simultaneously on a chronic (long-term) basis. Exposure scenarios of lesser duration or of lower concentrations and lower intake rates are assumed to be less. If there is no risk to human health under the bounding exposure scenario then it can be assumed that actual Site conditions are even less likely to pose a risk to human health.

Based on the Baseline Case period and the Closure Case, environmental data were selected to best delineate Site-wide impacts to the off-site public and on-site workers. Surface water, ground water, and air emissions were considered possible source terms for the Site. Data screening techniques used for surface and ground water are included in Appendix D ***{note to reviewers: Is this appendix going to be deleted? -- may need to move the water screening analysis to this section}***. Air quality data and the modeling techniques used to estimate ambient air concentrations were previously discussed in Sections B-3.1 through B-3.3.

For purposes of this assessment, the possible pathways for contaminants to reach members of the off-site public could come from the release of pollutants in air emissions and ground water wells. The routes of exposure would be inhalation of airborne contaminants and ingestion of contaminated ground water.

B-3.4.1 Nonradiological Air Contaminant Impact Analysis

CHEMICALS OF CONCERN. The air emission inventory data for the Site was based on reporting thresholds found in Colorado Air Quality Control Commission Regulation No. 3 as described in Appendix H. Contaminants of concern for point and fugitive dust sources at the Site include criteria pollutants such as sulfur dioxide, nitrogen dioxide, carbon monoxide, particulate matter less than 10 microns (PM-10), total suspended particulate matter (TSP), and lead. Hazardous air pollutants emitted from the Site include nitric acid, beryllium, carbon tetrachloride, hydrofluoric acid, hydrochloric acid, hydrogen sulfide, chloroform, dioctyl phthalate, chlorine, ammonia, methylene chloride, 1,1,1,-trichloroethane, methyl ethyl ketone, benzo(a)pyrene, and tetrachloroethylene.

The maximum reported facility emission rates for the air contaminants of concern were used to estimate ambient air concentrations of contaminants at receptor locations on-site, off-site and in nearby towns. Air concentrations were predicted using several air dispersion models as described in Section B-3.1.1. Of concern for this assessment are the maximum potential air concentrations at and around the Site that workers or the public could come in contact with. Therefore, human health risk was estimated for the maximum contaminant concentration predicted on-site, off-site, and in nearby towns. Air modeling results determined that the locations of the maximum concentrations varied with respect to the specific source and pollutant type. However, the risk assessment conservatively assumes that the exposed individual is in a hypothetical location where all chemicals are at the highest modeled concentrations. All maximum pollutant concentrations were found at receptors on the Site boundary or in close proximity to the Site boundary. All modeled air concentrations are total

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concentrations, which include ambient background levels and impacts from other nearby sources.

CHRONIC DAILY INTAKE. Analysis of the air modeling results revealed that the bounding exposure scenario would be a person who lived at the Site boundary exposed to the greatest air concentrations of all the chemicals of concern. A lifetime maximum exposure intake rate was calculated for an adult receptor living 70 years at this location, working at the home and out-of-doors, and therefore having the maximum conceivable exposure through inhalation. Exposure dose was estimated using standard EPA risk assessment methods (EPA 1989a). The following exposure equation was used.

Inhalation Exposure Equation:

$$\text{Intake (mg/kg-day)} = \frac{CA \times IR \times EF \times ED}{BW \times AT}$$

Where:

CA = Contaminant concentration in air: Maximum modeled concentration for each pollutant in mg/m^3

IR = Inhalation rate: 20 m^3/day (adult, average; EPA 1989a)

EF = Exposure frequency (365 days/year)

ED = Exposure duration: 70 years

BW = Body weight : 70 kg (adult, average; EPA 1989a)

AT = Averaging time period, in days, over which exposure is averaged: 365 days/year for 70 years.

Risk Characterization (Air)

WORKER EXPOSURE. The risk for on-site workers was determined through a direct comparison to 8-hour Occupational Safety and Health Administration or American Conference of Governmental Industrial Hygienists standards. An occupational-based hazard index was then calculated by dividing the maximum 8-hour pollutant concentration by the reference standard. An occupational hazard index less than one indicates a minimal risk to the on-site worker for that pollutant.

PUBLIC EXPOSURE. Health risks from site air emissions to the public were calculated for both criteria and hazardous air pollutants. Criteria pollutants are defined as those pollutants that have National Ambient Air Quality Standards (NAAQS) established by the EPA. The primary NAAQS have been developed to protect human health. The measure of risk for criteria pollutants such as sulfur dioxide and PM-10 is the hazard index which is calculated by dividing the total predicted concentration by the ambient standard for the respective averaging period. A hazard index less than one for public exposure to criteria pollutants indicates a minimal health risk for that particular pollutant.

The EPA Office of Research and Development has calculated acceptable intake values for chronic exposure to non-carcinogenic hazardous chemicals. Reference dose values are estimates of route-specific exposure levels that would not be expected to cause adverse human health effects when exposure occurs for a substantial portion of the person's lifetime. These values include safety factors to account for uncertainties associated with limitations of the toxicological database, including extrapolation of animal studies to humans and accounting for response variability from sensitive individuals. These values are updated quarterly and published in the *Health Effects Assessment Summary Tables* (EPA 1995b). Following more extensive review, they are finalized and provided through the EPA's *Integrated Risk Information System* database (EPA 1995c) which accepts updated toxicological information daily.

For hazardous air contaminants, a reference air concentration in mg/m^3 is provided rather than an intake in mg/kg-day. An inhalation reference concentration represents an acceptable ambient air concentration that would not be expected to cause adverse health effects even from long-term exposure. Reference concentrations can be converted to dose and used to compare to exposure doses or can be compared directly to air concentrations. However, it should be noted that conversion of the reference concentration to an inhalation reference dose may not reflect the actual dose that could be received through inhalation because it does not take into account the pharmikenetic and/or surface area adjustments required to estimate an "internal" dose. Another inherent uncertainty introduced by the conversion from a concentration to a dose is that some chemicals elicit route-of-entry effects not necessarily related to an internal dose. However, the simple conversion applied does not alter the hazard index results because the same conversion factors are applied to both the air concentrations and the reference concentrations prior to the calculation of the ratio.

The hazard quotient for hazardous chemical exposures for the public was calculated as follows:

$$\frac{\text{Exposure Dose (mg/kg day)}}{\text{Inhalation Reference Dose (mg/kg day)}} = \text{Hazard Quotient}$$

The hazard index is the sum of the hazard quotients for each chemical.

Exposure to Carcinogens

The Human Health Assessment Group of the EPA currently classifies specific chemicals as class A, B, C, D, or E carcinogens according to the weight of evidence available from animal or epidemiological studies. Cancer slope factors are estimated through the use of mathematical extrapolation models which estimate the largest possible linear slope for the dose response curve consistent with actual data. These values are upper-bound estimates which means that the real risk to an individual is not likely to exceed the upper-bound estimate and in fact may be lower (EPA 1989a). For carcinogenic chemicals, an EPA slope factor is multiplied by the exposure dose as shown below:

$$\text{Excess Individual Lifetime Cancer Risk} = \text{Exposure Dose (mg/kg day)} \times \text{Slope Factor (mg/kg day)}^{-1}$$

The data used to calculate all nonradiological human health risks from Site air emissions are presented in Tables B-38 and B-39 for Baseline Case conditions and the Closure Case, respectively. These tables include estimated air concentrations, exposure doses, inhalation reference doses, and cancer slope factors for each pollutant.

Table B-38. Risk of Predicted Air Releases from Hazardous Chemicals for the Baseline Case Period

Contaminants of Concern	Air Concentrations (ug/m^3)[a]		Intake (mg/kg-day)[b]		Health Effect Reference Values			Health Hazard Indicators			
								Co-located Worker		Off-Site Max.	Off-Site Maximum
	Co-located Worker[a]	Off-Site Max.[b]	Co-located Worker	Off-Site Max.[d]	Worker Exposure[c]	RfD/RfC[d] (ug/m^3)	Slope Factor[d] (mg/kg-day)^{1}	Hazardous[e]	Carcinogenic[f]	Hazardous[e]	Carcinogenic[f]
Sulfur dioxide	$2.31 \times 10^{+3}$	$1.08 \times 10^{+1}$	–	–	$5.00 \times 10^{+3}$	$8.00 \times 10^{+1}$	–	4.62×10^{-1}	–	1.35×10^{-1}	–
Nitrogen dioxide	$2.42 \times 10^{+3}$	$2.11 \times 10^{+1}$	–	–	$5.60 \times 10^{+3}$	$1.00 \times 10^{+2}$	–	4.33×10^{-1}	–	2.11×10^{-1}	–
Carbon monoxide (8-hr)	$5.01 \times 10^{+3}$	$4.30 \times 10^{+3}$	–	–	$4.00 \times 10^{+4}$	$1.00 \times 10^{+4}$	–	1.25×10^{-1}	–	4.30×10^{-1}	–
PM-10	$9.08 \times 10^{+1}$	$1.40 \times 10^{+1}$	–	–	$5.00 \times 10^{+3}$	$5.00 \times 10^{+1}$	–	1.82×10^{-2}	–	2.80×10^{-1}	–
TSP	$1.58 \times 10^{+2}$	$3.10 \times 10^{+1}$	–	–	$1.50 \times 10^{+4}$	$7.50 \times 10^{+1}$	–	1.05×10^{-2}	–	4.13×10^{-1}	–
Lead (quarterly)	1.70×10^{-10}	4.80×10^{-14}	–	–	$5.00 \times 10^{+1}$	$1.50 \times 10^{+0}$	–	3.40×10^{-12}	–	3.20×10^{-14}	–
Nitric acid	$3.34 \times 10^{+1}$	2.90×10^{-2}	–	8.29×10^{-6}	$5.00 \times 10^{+3}$	3.43×10^{-5}	–	6.68×10^{-3}	–	2.42×10^{-1}	–
Beryllium	4.00×10^{-3}	6.00×10^{-8}	1.12×10^{-7}	1.71×10^{-11}	$2.00 \times 10^{+0}$	–	$8.40 \times 10^{+0}$	2.00×10^{-3}	9.39×10^{-7}	–	1.44×10^{-10}
Carbon tetrachloride	$9.30 \times 10^{+0}$	1.00×10^{-2}	2.60×10^{-4}	2.86×10^{-6}	$1.26 \times 10^{+4}$	5.71×10^{-4}	5.30×10^{-2}	7.38×10^{-4}	1.38×10^{-5}	5.00×10^{-3}	1.51×10^{-7}
Hydrochloric acid	$5.10 \times 10^{+0}$	5.30×10^{-3}	–	1.51×10^{-6}	$7.00 \times 10^{+3}$	2.00×10^{-3}	–	7.29×10^{-4}	–	7.57×10^{-4}	–
Hydrofluoric acid	$2.60 \times 10^{+0}$	1.30×10^{-3}	–	3.71×10^{-7}	$2.50 \times 10^{+3}$	9.71×10^{-5}	–	1.04×10^{-3}	–	3.83×10^{-3}	–
Hydrogen sulfide	$9.80 \times 10^{+1}$	1.90×10^{-2}	–	5.43×10^{-6}	$1.40 \times 10^{+4}$	2.60×10^{-4}	–	7.00×10^{-3}	–	2.09×10^{-2}	–
Chloroform	$5.60 \times 10^{+0}$	2.90×10^{-3}	1.57×10^{-4}	8.29×10^{-7}	$9.78 \times 10^{+3}$	–	8.10×10^{-2}	5.73×10^{-4}	1.27×10^{-5}	–	6.71×10^{-8}
Dioctyl phthalate	7.00×10^{-1}	2.00×10^{-4}	–	5.71×10^{-8}	$5.00 \times 10^{+3}$	3.43×10^{-3}	–	1.40×10^{-4}	–	1.67×10^{-5}	–
Chlorine	$1.23 \times 10^{+1}$	6.30×10^{-3}	–	1.80×10^{-6}	$1.50 \times 10^{+3}$	1.14×10^{-4}	–	8.20×10^{-3}	–	1.58×10^{-2}	–
Ammonia	$3.58 \times 10^{+1}$	8.80×10^{-3}	–	2.51×10^{-6}	$1.70 \times 10^{+4}$	2.86×10^{-2}	–	2.11×10^{-3}	–	8.79×10^{-5}	–
Methylene chloride	$9.50 \times 10^{+0}$	4.20×10^{-3}	2.66×10^{-4}	1.20×10^{-6}	$1.77 \times 10^{+6}$	8.60×10^{-1}	1.60×10^{-3}	5.38×10^{-6}	4.25×10^{-7}	1.40×10^{-6}	1.92×10^{-9}
1,1,1,-Trichloroethane	$3.66 \times 10^{+3}$	2.10×10^{-2}	–	6.00×10^{-6}	$1.90 \times 10^{+6}$	2.86×10^{-1}	–	1.92×10^{-3}	–	2.10×10^{-5}	–
Methyl ethyl ketone	–	–	–	–	$5.90 \times 10^{+5}$	2.86×10^{-1}	–	–	–	–	–
Benzo(a)pyrene	–	–	–	–	$2.00 \times 10^{+2}$	8.57×10^{-8}	–	–	–	–	–
Tetrachloroethylene	–	–	–	–	$1.70 \times 10^{+5}$	1.14×10^{-1}	2.00×10^{-3}	–	–	–	–
Total	–	–	–	–	–	–	–	**$1.07 \times 10^{+0}$**	**2.78×10^{-5}**	**$1.34 \times 10^{+0}$**	**2.21×10^{-7}**

[a]Air concentrations are 8-hour averages for on-site and annual for off-site.
[B]Intake = contamination concentration x inhalation rate x exposure frequency x exposure duration + body weight + averaging time + conversion to mg.
[c]Occupational exposure limits are derived from OSHA, ACGIH, or NIOSH.
[d]Reference doses (mg/kg-day) and concentrations (mg/m^3) *for hazardous pollutant and slope factors are from the HEAST and IRIS table.* Reference concentrations for criteria and other pollutants are based on federal and state air quality standards.
[e]Hazard quotient = intake x RfD public hazardous exposure; on-site concentration/worker reference value for co-located worker; and off site concentration/air quality standard for criteria pollutants.
[f]Cancer risk = intake x slope factor.

Table B-39. Risk of Predicted Air Releases from Hazardous Chemicals–Closure Case

Contaminants of Concern	Air Concentrations (ug/m^3)[a]		Intake (mg/kg-day)[b]		Health Effect Reference Values			Health Hazard Indicators			
								Co-located Worker		Off-Site Max.	Off-Site Maximum
	Co-located Worker[a]	Off-Site Max.[b]	Co-located Worker	Off-Site Max.[d]	Worker Exposure[c]	RfD/RfC[d] (ug/m^3)	Slope Factor[d] (mg/kg-day)$^{-1}$	Hazardous[e]	Carcinogenic[f]	Hazardous[e]	Carcinogenic[f]
Sulfur dioxide	$2.31 \times 10^{+3}$	$1.08 \times 10^{+1}$	–	–	$5.00 \times 10^{+3}$	$8.00 \times 10^{+1}$	–	4.62×10^{-1}	–	1.35×10^{-1}	–
Nitrogen dioxide	$2.43 \times 10^{+3}$	$2.11 \times 10^{+1}$	–	–	$5.60 \times 10^{+3}$	$1.00 \times 10^{+2}$	–	4.33×10^{-1}	–	2.11×10^{-1}	–
Carbon monoxide (8-hr)	$5.01 \times 10^{+3}$	$4.30 \times 10^{+3}$	–	–	$4.00 \times 10^{+4}$	$1.00 \times 10^{+4}$	–	1.25×10^{-1}	–	4.30×10^{-1}	–
PM-10	$7.14 \times 10^{+2}$	$1.47 \times 10^{+1}$	–	–	$5.00 \times 10^{+3}$	$5.00 \times 10^{+1}$	–	1.43×10^{-1}	–	2.94×10^{-1}	–
TSP	$6.91 \times 10^{+2}$	$3.35 \times 10^{+1}$	–	–	$1.50 \times 10^{+4}$	$7.50 \times 10^{+1}$	–	4.60×10^{-2}	–	4.47×10^{-1}	–
Lead (quarterly)	1.70×10^{-10}	4.80×10^{-14}	–	–	$5.00 \times 10^{+1}$	$1.50 \times 10^{+0}$	–	3.40×10^{-12}	–	3.20×10^{-14}	–
Nitric acid	$3.34 \times 10^{+1}$	2.90×10^{-2}	–	8.29×10^{-6}	$5.00 \times 10^{+3}$	3.43×10^{-5}	–	6.68×10^{-3}	–	2.42×10^{-1}	–
Beryllium	7.00×10^{-3}	2.40×10^{-7}	1.96×10^{-7}	6.86×10^{-11}	$2.00 \times 10^{+0}$	–	$8.40 \times 10^{+0}$	3.50×10^{-3}	1.64×10^{-6}	–	5.76 x 10
Carbon tetrachloride	$2.27 \times 10^{+1}$	1.20×10^{-2}	6.35×10^{-4}	3.43×10^{-6}	$1.26 \times 10^{+4}$	5.71×10^{-4}	5.30×10^{-2}	1.80×10^{-3}	3.36×10^{-5}	6.00×10^{-3}	1.82×10^{-7}
Hydrochloric acid	$5.10 \times 10^{+0}$	6.20×10^{-3}	–	1.77×10^{-6}	$7.00 \times 10^{+3}$	2.00×10^{-3}	–	7.29×10^{-4}	–	8.86×10^{-4}	–
Hydrofluoric acid	$2.60 \times 10^{+0}$	1.30×10^{-3}	–	3.71×10^{-7}	$2.50 \times 10^{+3}$	9.71×10^{-5}	–	1.04×10^{-3}	–	3.83×10^{-3}	–
Hydrogen sulfide	$9.80 \times 10^{+1}$	1.90×10^{-2}	–	5.43×10^{-6}	$1.40 \times 10^{+4}$	2.60×10^{-4}	–	7.00×10^{-3}	–	2.09×10^{-2}	–
Chloroform	$5.60 \times 10^{+0}$	2.90×10^{-3}	1.57×10^{-4}	8.29×10^{-7}	$9.78 \times 10^{+3}$	–	8.10×10^{-2}	5.73×10^{-4}	1.27×10^{-5}	–	6.71×10^{-8}
Dioctyl phthalate	7.00×10^{-1}	2.00×10^{-4}	–	5.71×10^{-8}	$5.00 \times 10^{+3}$	3.43×10^{-3}	–	1.40×10^{-4}	–	1.67×10^{-5}	–
Chlorine	$1.23 \times 10^{+1}$	6.30×10^{-3}	–	1.80×10^{-6}	$1.50 \times 10^{+3}$	1.14×10^{-4}	–	8.20×10^{-3}	–	1.58×10^{-2}	–
Ammonia	$3.58 \times 10^{+1}$	8.80×10^{-3}	–	2.51×10^{-6}	$1.70 \times 10^{+4}$	2.86×10^{-2}	–	2.11×10^{-3}	–	8.79×10^{-5}	–
Methylene chloride	$2.28 \times 10^{+1}$	5.80×10^{-3}	6.37×10^{-4}	1.66×10^{-6}	$1.77 \times 10^{+6}$	8.60×10^{-1}	1.60×10^{-3}	1.29×10^{-5}	1.02×10^{-6}	1.93×10^{-6}	2.65×10^{-9}
1,1,1,-Trichloroethane	$3.66 \times 10^{+3}$	2.30×10^{-2}	–	6.57×10^{-6}	$1.90 \times 10^{+6}$	2.86×10^{-1}	–	1.92×10^{-3}	–	2.30×10^{-5}	–
Methyl ethyl ketone	$1.33 \times 10^{+1}$	1.70×10^{-3}	–	4.86×10^{-7}	$5.90 \times 10^{+5}$	2.86×10^{-1}	–	–	–	–	–

Benzo(a)pyrene	–	–	–	–	$2.00 \times 10^{+2}$	8.57×10^{-8}	–	–	–	–	–
Tetrachloroethylene	–	–	–	–	$1.70 \times 10^{+5}$	1.14×10^{-1}	2.00×10^{-3}	–	–	–	–
Total	–	–	–	–	–	–	–	**$1.20 \times 10^{+0}$**	**4.90×10^{-5}**	**$1.36 \times 10^{+0}$**	**2.52×10^{-7}**

[a]Air concentrations are 8-hour averages for on-site and annual for off-site.
[B]Intake = contamination concentration x inhalation rate x exposure frequency x exposure duration + body weight + averaging time + conversion to mg.
[c]Occupational exposure limits are derived from OSHA, ACGIH, or NIOSH.
[d]Reference doses (mg/kg-day) and concentrations (mg/m^3) for hazardous pollutant and slope factors are from the HEAST and IRIS table. Reference concentrations for criteria and other pollutants are based on federal and state air quality standards.
[e]Hazard quotient = intake x RfD public hazardous exposure; on-site concentration/worker reference value for co-located worker; and off site concentration/air quality standard for criteria pollutants.
[f]Cancer risk = intake x slope factor.

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{Additional references for Appendix B)

DOE 1996 — U.S. Department of Energy. *Environmental Assessment, Finding of No Significant Impact, and Response to Comments: Solid Residue Treatment, Repackaging and Storage.* DOE/EA-1120. Golden, Colorado. April 1996.

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Appendix C:
Accidents

C-1 Introduction

This appendix documents the details of the accident analysis for both radiological and nonradiological accidents for this Cumulative Impacts Document (CID). Potential accidents were arrayed by type (radiological or chemical) and initiator class (internal events or external events), and then processed through a screening analysis to focus attention on those accidents that contribute substantially to risk and/or allow discrimination between *Baseline* and *Closure* Cases in terms of environmental impact.

C-2 General Accident Information

Most of the analysis in this appendix was extracted from previous Department of Energy (DOE) National Environmental Policy Act (NEPA) documentation (e.g., environmental assessments and environmental impact statements) and safety analyses prepared for Rocky Flats Environmental Technology (RFETS or Site) or other DOE plutonium facilities. Many of the accident scenarios in this CID are modifications based on information developed for the *Draft Rocky Flats Site-Wide Environmental Impact Statement* (SWEIS) and the *Plutonium Storage Draft Environmental Impact Statement,* and their technical support documents[1]. In addition to those two documents, some of the most significant contributors include:

- *Environmental Assessment and Finding of No Significant Impact: Consolidation and Interim Storage of Special Nuclear Material at Rocky Flats Environmental Technology Site* (DOE 1995l) (hereafter referred to as *the SNM Consolidation EA*)

- *Final Environmental Impact Statement: Interim Management of Nuclear Materials* (DOE 1995gg)

- *Plutonium Finishing Plant Stabilization Final Environmental Impact Statement* (DOE 1996r)

- *Storage and Disposition of Weapons-Usable Fissile Materials Draft Programmatic Environmental Impact Statement (DOE 1996b)*

- *Defense Nuclear Facilities Safety Board Recommendation 94-3, Rocky Flats Environmental Technology Site, Implementation Plan: Task 9, Provide Recommendations and Bases for Interim SNM Management, Deliverable 9-1: Risk Assessment of Building 371 Baseline and Alternatives for Consolidation of SNM* (DOE 1995jj)

- *Building 371 Basis for Interim Operation* (Kaiser-Hill 1996f)

[1] These two EISs projects were canceled and final documentation were never completed. Therefore, this CID accident analysis updates the accident scenarios developed for those two draft EISs based on the information developed for the CID *Baseline* and *Closure* Cases.

Since the design of a new passive storage vault, and other new facilities such as for TRU waste shipping/staging are based on a conceptual design, the accident information developed for similar existing facilities or planned facilities at other DOE sites is used as a surrogate to estimate the risk for the *Closure* Case. Numerous accident scenarios and discussions were extracted from the above references with only minor changes, numerical adjustments, editing, and sometimes verbatim replication. These documents are initially referenced as each major topic is discussed.

Per current DOE requirements for a new nuclear facility, and subsequent to appropriate NEPA documentation for new facilities, additional accident analyses for identified major hazards will be provided in a *Preliminary Safety Analysis Report* to be issued during design and approved by DOE prior to the start of construction. A *Final Safety Analysis Report* will be prepared during the construction period and issued before nuclear operations begin as final documented evidence that the new facility can be operated in a manner that does not present any undo risk to the health and safety of workers and the public. (DOE 1989; DOE, 1992p)

The Site is a relatively large facility, covering some 384 acres in northern Jefferson County, Colorado, about 16 miles northwest of downtown Denver. The Site is situated in the center of a 6,262-acre buffer zone. There are more than 130 major structures in the facility with a total building floor space of 2.8 million square feet. The principal hazard at the Site arises from storage of plutonium in various chemical and physical forms and potential criticality accidents involving plutonium and enriched uranium.

Although there are more than 130 major facilities at the Site, only a limited number house substantial quantities of plutonium or highly enriched uranium during the *baseline* case. Those buildings are as follows:

- Building 371/374 (plutonium and highly enriched uranium, plutonium solution)
- Building 559 (plutonium)
- Building 569 (TRU waste)
- Building 664 (TRU waste)
- Building 707 (plutonium)
- Building 771/774 (plutonium, plutonium solution)
- Building 776/777 (plutonium)
- Building 779 (plutonium)
- Building 886 (highly enriched uranium solution)
- Building 991 (TRU waste, highly enriched uranium)

There are also numerous low level waste (LLW) storage facilities under *baseline* conditions (e.g., co-located with transuranic (TRU) wastes, Building 906 Centralized Low Level Waste Storage Facility, pondcrete tents, cargo containers, etc.). For the *closure* case, several new buildings are planned to be constructed or existing buildings modified for plutonium or waste storage. For example, a new Plutonium Interim Storage Vault will be constructed to store metal and oxide until they can be shipped to another DOE site for long term storage and permanent disposition. For TRU and LLW storage, Building 440 will be converted and a TRU shipping facility with temporary storage for staging shipments will be constructed.

The DOE *Plutonium Vulnerabilities Study* (DOE 1994n, EG&G 1994y) identified a number of concerns related to these buildings and plutonium stored at the Site. All of the plutonium facilities listed above have been identified with vulnerabilities, and six of them were ranked in the High Vulnerability class. Table C-1 lists a summary of the vulnerabilities from that 1994 study. Some of these vulnerabilities have been eliminated (e.g., hydrogen venting from drums and tanks/piping), but others (e.g., natural phenomena and aircraft crashes) will not be resolved until Site *closure* activities are implemented. Chapter 3 provides further

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information on activities performed during the *baseline* case or planned for the *closure* case to eliminate these vulnerabilities, or otherwise reduce the risks from them.

Table C-1. Buildings and Materials Vulnerable to Accidents at the Site

Vulnerability
Plutonium solution in tanks, piping, and holdup in process equipment could leak
Plutonium nitrate solutions can contact plastic-lined piping and leak
Plutonium nitrate solutions in plastic bottles in drums or gloveboxes could generate hydrogen gas
Plastic bottles containing plutonium nitrate/chloride solutions prone to cracking and leaking due to radiolysis
Highly enriched uranium nitrate solutions stored in Raschig rings tanks are insufficient to prevent a criticality
Plutonium metal in contact with plastic in sealed containers subject to pressurization and formation of pyrophoric plutonium hydride
Pyrophoric forms of plutonium (e.g., metal castings) improperly packaged
Packages of scrap/residue[1] in contact with plastic could generate hydrogen gas
Pyrochemical salt packages (calcium metal and calcium chloride) that are water absorbing, corrosive, and chemically reactive
Packages of plutonium peroxide cake, a chemically hazardous and unstable substance
Drums of ion exchange resin containing nitric acid and plutonium that are explosion hazards
Packages of grease contaminated with plutonium oxide and fluoride posing fire and radiation hazards
Unsealed plutonium scrap/residue containers in gloveboxes inappropriate for interim storage
Unsealed plutonium metal/oxide[2] containers in gloveboxes inappropriate for interim storage
Food pack cans of plutonium scrap/residues inappropriate for interim storage
Food pack cans of plutonium metal/oxide inappropriate for interim storage
Wet combustibles that are a fire hazard, including Ful-Flo filters loaded with organics and rags and paper soaked with plutonium solutions
"Infinity rooms" so contaminated that the doors have been sealed to prevent entry
Ventilation ductwork, gloveboxes, and supporting equipment with plutonium holdup that could be released to the environment in an accident
Buildings routinely contains flammable gases in cylinders (e.g., hydrogen, propane, acetylene) that are explosive and fire hazard
Some material stored in gloveboxes in rooms with weak exterior walls that cannot withstand an explosion within the room or natural phenomena events.
Credible natural phenomena events or aircraft crashes can breach most buildings allowing unfiltered releases or potential collapse of structures..

[1]Scrap/residue typical forms include pyrochemical salts, filters, graphite/carbides, impure oxides, fluorides, wet combustibles, dissolver heels, glass, and chlorides.

[2]Typical metal forms include pits, buttons, ingots, and metal scrap.

A summary of the accident analysis and risk assessment approach is presented in this appendix. The methodology used to assess risk of the *Baseline* and *Closure* cases is based on the general approach used to evaluate accidents for safety analysis reports and environmental assessments at RFETS. Conservative assumptions are made for portions of this assessment, based on the Site's current methods for developing Basis for Interim Operations (BIO) or Basis for Operations (BFO) documents[2]. Realistic estimates of risks are provided for risk management purposes by modeling consequences to the public for typical weather (rather than worst case) conditions and by providing best estimates of frequency of occurrences. Risk is expressed quantitatively as the product of potential consequences of an accident times its expected annual frequency of occurrence, and summed for all accidents evaluated. Risk is presented for two public receptors: a maximally exposed off-site individual (MOI) at the site boundary and population within 50 miles of the site, and for the co-located worker assumed to be located 100

[2] A BIO is an interim safety analysis authorization basis until the facility's existing final safety analysis report (FSAR) is upgraded to DOE Order 5480.23, Nuclear Safety Analysis Reports, or an exemption from FSAR upgrading is granted. A BFO is the Site's necessary and sufficient approach to establishing a safety analysis authorization basis that will provide equivalency to the BIO/FSAR upgrade requirements.

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meters downwind of the release To evaluate potential consequences from radioactive releases at RFETS, the amount of plutonium made airborne (called a source term) by an accident is estimated. This source term is then converted into a concentration in air that an individual could be exposed to. Based on a duration of exposure and current dose assessment methodology, an estimate of a radiological dose commitment or estimate of latent cancer fatalities to an individual or population can be made. DOE defines (DOE, 1992p) risk from an accident as "the quantitative or qualitative expression of possible loss that considers both the probability that a hazard will cause harm and the consequences of that event." Probability terms are usually expressed as a probability or frequency of occurrence (for example, $1x10^{-6}$/yr, return period of once in one million years, or one chance in one million per year). When a consequence (for example, rem of radiological exposure) is multiplied by the probability of occurrence, the result is a risk estimate in units of consequences per year (for example, rem/yr. In this document, risk has been evaluated for a spectrum of bounding accidents. Because all possible paths to those accidents have not been evaluated, the result is relative risk, and that is what is presented in this analysis.

A spectrum of accident scenarios resulting in a release of plutonium to the environment has been evaluated previously for the *Rocky Flats Plant Final Environmental Impact Statement* (RFP FEIS) (DOE 1980), the *Long Range Rocky Flats Utilization Study* (DOE 1982), and in individual plutonium handling facilities *Final Safety Analysis Reports* (FSARs 1980s). Hazards and their controls (i.e., engineered safety features and administrative controls) were identified and evaluated in order to estimate the probabilities and consequences of accidents. These documents were reviewed in order to establish a set of bounding accidents for comparison between the *Baseline* Case and the *Closure* Case. Although not all potential accidents were addressed, those that were postulated have consequences and risks that are expected to envelop the consequences and risks of an operating facility. In this manner, no other credible accidents with an expected frequency of occurrence greater than $1x10^{-7}$/yr are anticipated that will have consequences and risks larger than those described in this section.

Numerical values are generally presented in scientific or computer notation, e.g., $1x10^2$ = 1E+2 = 100, and $1x10^{-2}$ = 1E-2 = 0.01. Numerical estimates of risks in this assessment are intended to be used to demonstrate the relative differences between the *Baseline* and *Closure* Cases. In some instances, more than one significant digit may be presented for numerical estimates to identify differences between the two cases. This does not imply that environmental impacts can be predicted to that degree of precision. These numerical risk estimates should generally be viewed as order-of-magnitude estimates and are often presented as a single significant digit. Uncertainties in all of these values are generally large and were not quantitatively addressed in this assessment. The absolute values of risk generally do not have meaning, except for comparisons to other risk estimates (e.g., comparison of population risk to the risk from natural background radiation, or to DOE or contractor risk acceptance criteria).

Three general classes of events are considered: internal events, and external events, and natural phenomena events. Internal events are those events originating within the facilities at the Site that result from the storage or processing of materials and do not require an external influence (e.g., various combinations of component or system failures and/or human errors). External events are potential accident initiators originating outside the engineered systems of the facility in question and include a variety of man-made hazards, such as aircraft crashes. Natural phenomena events have initiators originating outside the facility or area and include such events as floods. This appendix documents the screening methodology used in identifying potential event initiators which must be analyzed in detail and applies that methodology to produce a screening analysis for the Site.

A review was conducted of previous safety and risk evaluations for Site facilities to identify potentially significant internal event scenarios. Consideration was also given to initiators and event scenarios found to be important in probabilistic risk assessments of other types of nuclear

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facilities (including commercial nuclear power plants, DOE production reactors, spent nuclear fuel storage installations, and high- and low-level waste repositories).[3]

The external event screening methodology selected for application draws on previous methods for analyzing external events as used in the nuclear industry. In particular, it employs the screening methods developed for the U.S. Nuclear Regulatory Commission Individual Plant Examination for External Events (NRC 1991a, NRC 1991b) program and the Nuclear Regulatory Commission-sponsored Risk Methods Integration and Evaluation Program (NRC 1991c).

There are considerable portions of information about the location (building/room), chemical form, physical form, and mass of materials that cannot be reported in the CID because the information remains classified. An unclassified inventory of special nuclear material (SNM), plutonium residues, TRU waste, and plutonium holdup is reported in Chapter 2 of the CID. When necessary (e.g., to estimate releases from seismic collapse of buildings), the actual classified inventories by building were reviewed and used in the risk assessment.

C-3 Potential Accident Candidates for Screening

Two important considerations affected the accident analysis for the Site:

- Accidents involving uranium are considered only if a criticality occurs. Otherwise, the doses resulting from release and dispersal of enriched uranium or depleted uranium are quite small compared with doses resulting from release and dispersal of plutonium. It was concluded that these small doses would not impact the differences between the *Baseline* and *Closure* cases. Thus, uranium accidents apart from criticality considerations were not considered further in the CID accident analysis. This is also true for most other radioisotopes except for americium which was evaluated.
- Unless a plutonium accident occurs on a loading dock or in transit, a substantial release to the environment cannot occur unless the accident involves a consequential (dependent) failure of the high-efficiency particulate air filtration system or otherwise breaches in an exterior wall (e.g., explosion). Dozens of accident analyses in plutonium buildings' *Final Safety Analysis Reports* (FSARs 1980s) and the 1980 RFP *Final Environmental Impact Statement* (DOE 1980) were reviewed, and these analyses make clear that the high-efficiency particulate air (HEPA) filtration system results in extremely large reductions in the source term. Typical releases that take place through the two to four stages of HEPA filters are a very small fraction of a gram of plutonium. Such extremely small releases do not affect the risk estimates for the *Baseline* and *Closure* cases, unless all accidents are filtered. However, current safety analysis methods only allow credit for HEPA filters if they are periodically inspected and re-tested, and the Site now only surveils one or two stages of HEPA filtration for each plutonium building. Therefore, filtered releases may be a risk-significant event if the frequency of occurrence is high.

C-3.1 Accident Screening Methodology

The approach adopted for accident screening for the Site is a variation of an approach called "progressive screening." There are three important goals of accident screening.

First, the analysis should be complete in that all events are considered. It is recognized that it is not possible to formally demonstrate the elusive goal of "completeness." There are

[3]As part of the detailed analysis, a review was conducted of Site plutonium and uranium building *Safety Analysis Report* documentation to identify whether any additional internal event initiators/scenarios need to be considered.

inevitably some accident scenarios that are not addressed for one reason or another. However, the goal of the screening analysis is to be as comprehensive as possible in order to provide reasonable assurance that any scenarios not explicitly addressed are relatively low in frequency such that they do not contribute substantially to risk.

Second, by following screening criteria, events with a higher potential for risk are identified for more detailed analysis. The Site is large and relatively diverse in the types of facilities and in activities to be conducted under the *Baseline* and *Closure* Cases. The number of individual accident scenarios (combinations of initiating events and dependent or independent failures, which could result in a radiological release to the environment) that could be defined would be extraordinarily large. To illustrate, in a commercial nuclear power plant there are often many millions of accident scenarios identified (however, all but a small percentage are so unlikely that they do not contribute substantially to risk). For the Site, it must be expected that a full scope risk assessment of all the plutonium and uranium facilities at the Site would result in identification of millions of accident scenarios. Without resorting to a full-scope risk assessment approach, the screening approach efficiently identifies the accident scenarios with a higher potential for risk for detailed consideration and consequence analysis.

Third, the selected events are analyzed in depth by taking into account the unique features of the potential hazard posed by the event, the "fragility" of structures and equipment (i.e., the resistance of structures and equipment to the environment created by the event), and the frequency of the initiating event.

The first goal ensures that no important events are overlooked. The second goal directs the allocation of limited analytical resources to the assessment of only the most important events. The third goal ensures that differences between external events and internal events (e.g., the greater potential for common-cause failures and the potential for structural failures and failures of passive components) are recognized and explicitly treated (NRC 1991c).

Several steps are required to implement this method:

1. Screening criteria are defined.
2. Master lists of potential internal and external event initiators are formulated.
3. A progressive screening analysis is performed for the external events where events that are not applicable to the Site are screened from further analysis (e.g., coastal erosion would have no impact on a facility located far inland).
4. For those events surviving the first stage of screening, a conservative bounding analysis is performed to ascertain whether the event frequency exceeds 1×10^{-6} per year (conservatively assessed) or 1×10^{-7} per year (realistically assessed). If the event frequency falls below these screening values, no further analysis is performed (i.e., the event screens) (DOE 1990b).[4]
5. Events which survive the screening analysis are identified for more detailed evaluation by considering bounding accidents applicable to each alternative.

In lieu of a probabilistic risk assessment, and in order to provide a reasonable assurance of completeness, a review has been conducted of previous safety and risk evaluations for the Site to identify potentially significant internal event scenarios. A variety of source documents was reviewed for this purpose. The primary sources for information on internal events resulting in

[4]The screening criterion used in the Nuclear Regulatory Commission-sponsored RMIEP program was 1.0×10^{-7} per year. The report documenting that screening criterion, although published in 1991, was completed in 1985. More recent standards for screening criteria (such as the NRC's IPEEE program guidance and DOE Orders 6430.1A and 5481.1A) mandate use of the 1.0×10^{-6} screening criterion identified above. The 1.0×10^{-6} screening criterion was used in the risk assessment of the 'N' Reactor in 1990 (DOE 1990b).

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potential actinide release or criticality have been the Safety Analysis Reports for the various facilities, a variety of environmental assessments, the *Rocky Flats Risk Assessment Guide* (EG&G 1994w), and other special reports on specific topics (such as earthquakes, transportation accidents, and aircraft crash). In addition, the internal event screening approach drew upon probabilistic risk assessments of other nuclear facilities such as nuclear power plants, spent fuel storage installations (EPRI 1984), and high- and low-level waste repositories), environmental assessments, and environmental impact statements of other DOE facilities.

For external events, standard listings of events were consulted (NRC 1983a, DOE 1990b).[5]

C-3.2 Screening Analysis

A set of screening criteria is formulated for external events to minimize the possibility of omitting substantial risk contributors while reducing the amount of detailed analyses to manageable proportions. For this analysis, the Probabilistic Risk Assessment Procedures Guide screening criteria have been adapted as these screening criteria have been subjected to more than a decade of peer review and extensive use. (Criterion 5 is taken from DOE 1990; Criterion 6 has been newly added for this report.)

An external event is excluded from further analysis ("screened") (NRC 1991c, DOE 1990b) if the following events occur:

1. The event is of equal or lesser damage potential than the events for which the facility has been designed (i.e., design basis accidents). No release is assumed for structures, systems, and components designed as safety class to protect the public (e.g., design basis earthquake or Department of Transportation Type B shipping package requirements to withstand specified accident conditions). This is based on the consideration that the probability that a substantial error has been made in design, fabrication, and/or construction which invalidates the design basis is sufficiently low that the accident is not considered credible.[6] For screening purposes, it was assumed that there was a 0.1 chance of a substantial error being committed during design, fabrication or construction; a 0.5 chance that the error is sufficiently grave that it resulted in a structure, system, or component failure during an external event; and a 0.1 chance that the error was not detected prior to the event occurring. This results in a conditional screening probability of 5×10^{-3} of a substantial error being committed and not detected, which invalidates the design basis.[7] Therefore, events less than the design basis are not considered unless the equipment that could cause a release was not designed as safety class (which is the

[5]The listing in the Nuclear Regulatory Commission's *Probabilistic Risk Assessment Procedures Guide* (NRC 1983a) is an adaptation of a listing first published in ANSI Standard 2.12-1978. (ANSI 1978).

[6]The Nuclear Regulatory Commission's Office for Analysis and Evaluation of Operational Data has performed a study of design, fabrication, and installation errors in the commercial nuclear industry (NRC 1987a). It should be noted that this study concerns commercial nuclear power plants, many of which were designed, fabricated, and constructed under the quality assurance controls imposed by Nuclear Regulatory Commission regulations (Appendix B to 10 CFR 50). Similar criteria were not always applied to the design, fabrication, and construction of facilities at the Site. Accordingly, it must be recognized that the potential for a significant DFI error is higher for some facilities at the Site. This is not to say that due care was not exercised in the design, fabrication, and construction of the Site. Rather, it is a common sense recognition of the value of QA controls on these processes.

[7]In the context of seismic risk assessments, sensitivity studies have been conducted evaluating the potential risk significance of design and construction errors. These studies have shown that only gross errors of very large magnitude have any observable influence on seismic risk assessments (EPRI 1985). It is judged that similar insights probably apply to other types of events as well due to conservatism in design practices (i.e., margins of safety). Another point of departure is provided by an estimate of the conditional probability of a weak spent fuel storage cask, estimated at a conditional probability of 2×10^{-3} per cask (EPRI 1984).

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case for all of the plutonium buildings except Building 371 which were built before safety class requirements were established).

2. The event has a substantially lower mean frequency of occurrence than other events with similar uncertainties and could not result in worse consequences than those events. In this case, the uncertainty is judged by the analyst as not substantially influencing the total risk.

3. The event cannot occur close enough to the facility to affect it. This is a function of the magnitude of the event and the proximity of the event to the facility. Potential examples of such events are landslides and avalanches.

4. The event is included in the definition of another event. For example, storm surges and seiches are included in external flooding.

5. The event is slow in developing and there is sufficient time to eliminate the source of the threat or to provide an adequate response to the threat. (This necessarily requires some consideration of the likelihood that the event materializes and that the response to the threat is either not made or is sufficiently delayed that a hazardous condition is permitted to develop.)

6. The event represents a potentially cataclysmic event such that the consequences of the event would not be measurably impacted by the destruction of the facility under evaluation (e.g., impact of a large meteorite or asteroid on the Site, producing a large impact crater). Although severe earthquakes could cause cataclysmic consequences throughout the region unrelated to release of plutonium (e.g., large number of fatalities due to collapsing buildings), it was included in the analysis to provide a perspectives for reducing risks to the public during the *closure* case timeframe.

7. The event survived preliminary screening.

The screening analysis for external events at the Site is identified in Table C-2. Application of the above screening criteria resulted in the identification of the events listed in Table C-3 for no further detailed assessment for their impact on the Site (i.e., they were screened out). Progressive screening was applied to some of these events. Bounding analyses resulted in screening additional accidents based on the 1×10^{-6} to 1×10^{-7} per year accident frequency screening criterion.

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Table C-2. Preliminary Site Accident Screening

External Event	Applicable Criterion	Remarks and Screening Assessment
Aircraft impact	7	Site-specific hazard requiring further study; includes consideration of light and heavy aircraft, military aircraft, and helicopters; requires consideration of direct impact, slide distance, and post-crash fire/explosion due to aircraft fuel spills.
Avalanche	3	The Site is located four miles from the foot of the front range of the Rocky Mountains; this is judged to be too distant for an avalanche to impact the Site.
Biological event	1, 5	The Site facilities are not subject to biological events that might be a factor at other types of facilities (e.g., such as fish or waterborne vegetation blocking cooling water intakes at power plants). Further, any such event would tend to be slow in developing, which would provide warning of the need to take remedial or protective measures for Site facilities.
Chemical/hazardous materials accidents	7	Site-specific hazard requiring further study.
Climatic Change	5, 6	Potentially cataclysmic impact (glaciation); however, it would be expected to occur sufficiently slowly to permit implementation of protective or remedial actions such as removal of SNM to a more protected site; global warming resulting in melting of the polar ice caps would not result in flooding at the Site due to the Site elevation.
Coastal erosion	3	Rocky Flats is not a coastal site.
Criticality (uranium)	7	Site-specific and operation-specific event requiring further analysis.
Criticality (plutonium)	7	Site-specific and operation-specific event requiring further analysis.
Dam failure	3	There are no dams upslope in the area; Site impoundments drain downslope away from the plutonium and uranium buildings.
Drought	1, 5	Excluded on the basis that the need for cooling water is minimal, and that the long lead time available would afford ample opportunity to bring sufficient water to the Site to maintain safe conditions; even if cooling cannot be maintained and pyrophoric material ignites, the high-efficiency particulate air filtration system will substantially mitigate the release and the resulting risk will be very low.
Dust storm	1	Dust storms could result in loss of off-site power, but at a lower frequency of occurrence than random off-site power failure. In order for dust storms to result in a large release of plutonium, an accident would have to be initiated and the high-efficiency particulate air filters would have to fail. While the outer filter could clog and fail, it is unlikely that the dust storm would last long enough and be sufficiently severe that multi-stage high-efficiency particulate air filters would fail.
Earthquake	7	Site-specific hazard requiring further study.
Explosion	7	Use of propane for laboratory analyses and acetylene for infrequently welding by maintenance requires further analysis. Natural gas is used at the Site, but has been eliminated from plutonium processing areas other than involving only low level wastes.
Fire (external)	1, 3	External fires (wildfires) are possible; however, Site vegetation is largely limited to grasslands (82.3%), with marshlands, shrublands, and woodlands covering 5.7% and industrial facilities covering the remaining 12.0% (EG&G 1994b). The area around Site buildings has been cleared, reducing the potential for spread of external fires to buildings. Grassland fires can spread quickly and produce substantial quantities of smoke. The consequences of such fires would be limited to loss of off-site power and/or failures of diesel generators (due to smoke ingestion). External fires could contribute to loss of off-site power/station blackout, but at a much lower frequency of occurrence than random failures. Fuel tank trucks are present on the Site so infrequently that fires caused by accidents involving such trucks would screen on frequency. Fuel storage tanks are surrounded by berms to prevent fuel spread.
Fire (internal, other than dock fires and spontaneous combustion)	7	Such fires requiring further analysis include fires in gloveboxes, fires in vaults, and room fires
Fire (spontaneous combustion of pyrophoric oxide)	7	Pyrophoric corrosion products on Pu metal may spontaneously ignite if current Site procedures fail or the 50-year storage container leaks and not detected by periodic surveillances.
Flooding (external)	7	Site-specific hazard requiring further study; requires consideration of extreme precipitation, melting of ice and snow, and dam failures (perhaps seismically induced).
Flooding (internal)	7	Structure- and system-specific hazard requiring further study; requires consideration of all piping systems (including process systems, cooling systems, and fire protection water systems).

Fog	1, 4	Fog is not an inherent hazard for the Site facilities. Fog could, however, increase the frequency of man-made hazards arising from transportation by surface vehicles and aircraft and is considered to be reflected in the frequency of such accidents.
Frost	1, 4	Structural loads induced by frost are much lower than snow and ice loads.
Hail	1, 4	As a source of missiles, hail is much less damaging than tornado missiles. Impacts on the power grid are included under internal events loss of off-site power, to which hail is one possible contributor.
High tide, high lake level, or high river level	4, 5	Included under flooding (external); in addition, these events are either predictable (high tide) or have substantial lead time in developing.
Hurricane	3, 4	This Site is well inland and thus protected from the more severe influences of hurricanes; any impacts from hurricanes are included under flooding (external), winds (straight), and tornadoes.
Ice	4, 5	Snow and ice loads were considered in the design of Site buildings; only Building 886 has been identified as susceptible to failure due to snow and ice loads, and the contribution here would only be to the potential for uranium criticality; this contribution is reflected in the uranium criticality frequency.
Nearby Industrial facility accident	3	No industrial facilities are sufficiently near to the Site to cause damage to Site facilities.
Landslide	3	The Site facilities are too far from high ground to be affected by landslides.
Lightning	1	Lightning protection is considered in facility design (EG&G 1992f) and is assumed to be adequately maintained to prevent potential roof fires. Lightning contributes to loss of normal power which was evaluated..
Low lake or river water level	3, 5	The Site is not located sufficiently near a lake or river and does not require cooling water from such a source. Moreover, such conditions are slow to develop and would afford adequate lead time to devise and implement remedial or protective measures to counter the threat.
Meteorite/asteroid impact	6	All sites have approximately the same frequency of occurrence for meteorite impacts (8.9×10^{-7} per year for impact of a meteorite one pound and larger, per square mile) (Rockwell 1977); consideration of the small fraction of a mile occupied by plutonium facilities (0.05 square miles) would result in this event screening. Asteroid impacts are lower in frequency, but affect larger areas, and would cause widespread devastation such that any damage to and consequences resulting from the Site facilities would not measurably affect the consequences of the impact event.
Pipeline accident	7	Site-specific hazard requiring further study; natural gas pipelines are known to pass through some Site facilities.
Precipitation extremes	4	Included under flooding (external).
Process accident (line breach)	4	This event could result in a criticality event and is included in the frequency of both uranium and plutonium solution criticalities.
River diversion	3	The Site is not located near a river nor dependent upon one for cooling water supply.
Sabotage and terrorism	7	Site- and facility-specific hazard requiring further study.
Sandstorm	1, 3	The Site is not located sufficiently near to sand to be affected by a sandstorm; impacts should be bounded by dust storm (i.e., loss of off-site power).
Satellite orbital decay	2	All sites at this latitude have approximately the same frequency of occurrence; many satellites would burn up during re-entry into the atmosphere; much of the land area at this latitude is water.
Seiche	4	Included under flooding (external).
Snow	4, 5	Snow and ice loads were considered in the design of Site buildings; only Building 886 has been identified as susceptible to failure due to snow and ice loads, and the contribution here would be only to the potential for uranium criticality; this contribution is reflected in the uranium criticality frequency.
Soil shrink-swell consolidation	1, 5	Site suitability evaluation generally precludes the effects of this hazard; moreover, such effects occur over a long period of time, permitting remedial or protective actions to be taken.
Spill (container falls)	7	Site- and facility-specific hazard requiring further study.
Spill (container punctured)	7	Site- and facility-specific hazard requiring further study.
Storm surge	3, 4	Included under flooding (external).
Temperature extremes	1	Facilities are designed with respect to resulting thermal stresses and embrittlement; facilities also provided with climate control (HVAC) to limit the impact of temperature extremes on building contents. Should HVAC fail during extreme cold weather, the Site would implement a freeze protection program.
Tornado	7	Site-specific hazard requiring further study (including both rotational winds and tornado missiles).

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Toxic gases	4	Included under chemical accidents.
Transportation accident	7	Site-specific hazard requiring further study.
Tsunami	3, 4	The Site is not located near a body of water capable of being sufficiently affected by a tsunami; included under flooding (external) and earthquakes.
Turbine missile	7	Facility-specific hazard requiring further study; requires consideration of turbines on emergency power generators.
Volcanic activity	3	The nearest active volcanoes to the Site are in the Cascade Range in Washington, Oregon, and California; while these volcanoes are capable of extremely violent eruptions producing massive ash falls over large areas (such as the Mt. Mazama eruption which produced Crater Lake), the impacts on the Site would be expected to be minimal; an impact possible on off-site power reliability is noted, however, the Bonneville Power Administration transmission lines and local power distribution networks continued to operate during the 1980s-era eruption of Mt. St. Helen's (including the large eruption of May 18, 1980), despite ashfalls of six inches or more in some locations.
Waves	4	Included under flooding (external).
Wind (straight)	7	Site-specific hazard requiring further study.

Table C-3. Postulated Accidents Eliminated by Initial Screening Process

Avalanche	Hail	River diversion
Biological events	High tides, High lake level, high river level	Sandstorms
Climatic change	Ice, Frost	Satellite orbital decay
Coastal erosion	Nearby Industrial facility accidents	Snow (except for B886)
Dam failure	Landslides	Soil shrink-swell consolidation
Drought	Lightning	Temperature extremes
Dust storms	Low lake or river water level	Tsunamis
External fires	Meteorite or asteroid impact	Volcanic activity
Fire (external)	Pipeline accidents	Waves
Fog		

C-3.3 Accidents Screened Based on Bounding Analyses

This section presents bounding analyses of some accidents that survived initial screening. A bounding analysis can be either based on postulated consequences, or greatest risks, or both. A bounding consequence analysis is one in which the source term, exposures, and estimated impacts are overstated (i.e., they are upper bounds) and will be greater than other similar postulated accident scenarios. A bounding risk analysis is one where the dominant accident (considering both consequences and frequency of occurrence) is greater than other similar accidents of the same type. Another form of bounding risk analysis is the use of the 1×10^{-6} per year to 1×10^{-7} per year screening criteria which implies that consequences of lesser probability accidents would not be significantly greater than those analyzed such that their risks are greater.

C-3.3.1 Flooding (External)

A review of external flooding considerations was performed. There are no dams or tributary streams that would support flooding of the Site should they fail or overflow. The Site watershed is small and is well protected from excessive runoff and flooding by good drainage characteristics and by a diversion canal west of Buildings 371 and 374. The Site is also drained by five streams running from west-to-east (North Walnut Creek, South Walnut Creek, Woman Creek, Rock Creek, and an unnamed tributary of Walnut Creek). Hydrological data indicate that the Site will not be flooded by a 100-year storm (Rockwell 1981, EG&G 1992w, EG&G 1994b). The highest point on the Site is the west entrance at 6,200 feet above mean sea level, and the lowest point is at 5,600 feet above mean sea level where Woman Creek leaves the Site (EG&G 1990d).

Impoundments on the Site will not flood the Site; rather the impoundments drain away from the Site buildings. Failure of the impoundments during severe earthquakes would not affect Site buildings (rather, the earthquake itself would be a severe challenge to the Site buildings). As the Site is not bordered by or downstream of a lake or river, high tides, high water levels, waves, or storm surges are not a concern. Hurricanes would not likely affect the Site. Seiches and tsunamis similarly would not affect the Site.

The maximum rainfall potential for the Site is estimated to have a frequency of 1×10^{-3} per year, and the Site drainage system has been found to accommodate this rainfall without flooding of the Site, if properly maintained. According to the draft Site *Safety Analysis Report*, " Although the frequency of thunderstorms is moderately high, heavy runoff is adequately drained by creeks that traverse the Site. Severe flooding is considered highly improbable because of the good drainage and because the stream beds are lower than the Site buildings." (EG&G 1990d). A 1988 DOE report estimates the frequency of flooding above 5,950 National Geodetic Vertical Datum, which is the elevation of the lowest Site structure, at less than 1×10^{-5} per year (LLNL 1988).

When frequencies of 1×10^{-4} are approached in terms of flooding, one is into the frequency range for glaciation (ice ages). Such phenomena are slow in developing, providing adequate time for SNM to be packaged and shipped to less vulnerable locations. By the time substantial melting from such an event would occur, it is presumed that the SNM would have been removed from the Site. Based on these considerations, external flooding is screened from further analysis.

C-3.3.2 Flooding (Internal)

Internal flooding could occur in a variety of buildings due to leaks from process piping, fire protection water piping, or other piping. Most of the plutonium buildings function as storage buildings that would be largely unaffected by flooding from pipe leaks or breaks. Internal flooding would most likely result in spread of contamination from gloveboxes resulting in substantial decontamination efforts, but minimal releases within the building.

The most substantial impact resulting from flooding is the potential for criticality. Vaults, canyons, and valve corridors are not covered by water-based fire protection systems (Rockwell 1981); this reduces the likelihood that a fire protection system-based flooding event would result in criticality. In addition, the buildings are protected by drains, curbs, and drain tanks.

Small pipe break frequencies in commercial nuclear power plant risk studies are typically clustered around 1×10^{-3} per year, and these facilities have far more piping than is present in buildings at the Site. The piping at the Site is subjected to regular inspection and maintenance for contamination-control purposes. Also, the plutonium and uranium buildings at the Site have accumulated approximately 300 building-years of operating experience without a flood-induced criticality event.[8] The accident frequency for plutonium and uranium criticality (on the order of 10^{-4} per year) is considered to adequately represent this possibility. This frequency is also greater than or on the same order of magnitude as the likelihood of seismic-induce criticalities or an aircraft crash resulting in a criticality (which occurs at a much lower

[8]A recent assessment of pipe failure frequency for Building 371 states (EG&G 1994aa), "A conservative piping system failure rate in the nuclear industry is on the order of 10^{-4} failures per year per system. The lack of high pressure in the Building 371 piping and the lack of a flaw propagation mechanism of significance in this piping is expected to decrease this failure rate by one to two orders of magnitude. Another order of magnitude reduction in the likelihood of failure can be attributed to the limited amount of piping involved. Conservatively, the elevated piping may have a failure rate on the order of 10^{-6} per year."

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frequency). Accordingly, internal flooding is screened from further analysis on the basis that the event is included in the definition of another event.

C-3.3.3 Pipeline Accident

Pipeline accidents pose a potential fire/explosion risk to industrial facilities such as the Site plutonium buildings. Previous nuclear power plant probabilistic risk assessment studies have estimated the random failure probability of a natural gas pipeline at 4.5×10^{-4} per year (NRC 1991c). A natural gas pipeline enters the Site in the 800 Area Complex at the periphery of the Site and is distributed throughout the Site via above-ground steam stations. Very small natural gas lines enter some of the buildings on-site for heating and non-plutonium processing purposes; natural gas releases from these small lines that could result in an explosion outdoors or in support areas of the plutonium buildings are assumed to not be sufficient to pose a hazard to the plutonium stored in the buildings (however, this hazard is still being evaluated by the Draft Site Safety Analysis Report project). Previous use of natural gas in plutonium processing areas other than involving LLW have been discontinued. Accordingly, based on probability and safety analysis grounds, pipeline accidents are excluded from detailed evaluation.

C-3.3.4 Sabotage and Terrorism

Acts of vandalism, sabotage, and terrorism could potentially result in a radiological and/or chemical accident at the Site (Rand 1982). The potential for such impacts is indicated by, for example, vehicle bombings at the U.S. Embassy in Beirut, Lebanon; the World Trade Center in New York; and the federal building in Oklahoma City. There is also a history of events at commercial nuclear power plants, including a series of vandalism events in the 1980s and a vehicular intrusion event that penetrated the Protected Area at the Three Mile Island Unit 1 nuclear power plant on February 7, 1993 (NRC 1993a).

These events can involve a variety of initiating events and failure scenarios depending upon the scenarios followed by the perpetrators (e.g., use of flammable, incendiary, or explosive devices; use of weaponry; choice of targets; etc.). The perpetrators can be insiders (personnel with authorized access to the Site facilities) or outsiders (including visitors, guests of Site personnel, members of foreign paramilitary or military organizations, etc.).

Acts of vandalism, sabotage, and terrorism are related to the human will to cause damage and are extraordinarily complex to analyze in the context of a probabilistic estimate of risk. Defining a "hazard curve" depicting the relationship between frequency of occurrence and severity of impacts is essentially impossible for such acts.

Even if there were sufficient and reliable data on past acts, any assumption that past patterns will represent future actions is fraught with large uncertainties. The hazard curve must account for numerous intangible factors such as political conditions in the U.S. and internationally; interpersonal relationships of Site employees and their families, friends, and acquaintances; availability of the tools of sabotage and terrorism; variations in the human and equipment performance of the protection force and systems at the Site; and a host of other factors.

It is not feasible to make useful and defensible estimates of public risks associated with acts of vandalism, sabotage, and terrorism at nuclear and/or non-nuclear facilities. Moreover, even if such estimates were possible, the basis for the estimates could not be extensively discussed due to security and safeguards restrictions. Accordingly, acts of vandalism, sabotage, and terrorism, although they represent possible sources of accidents and risk (both radiological and chemical), are screened from further analysis due to the inability to represent their frequency or their consequences in a meaningful format (NRC 1994a). Instead, DOE security and safeguards Orders and directives require that radiological sabotage be evaluated to assure that sufficient safeguards are identified and implemented.

C-3.3.5 Tornadoes

Tornado data for Colorado from 1954 through 1983 project a tornado occurrence rate for the state of 9.2 x 10^{-6} per square mile (NRC 1986). The previous design basis tornado for the Site with a frequency of occurrence of 1 x 10^{-6} per year corresponds to a tornado wind speed of 185 mph (135 mph rotational, 50 mph translational) (EG&G 1994w). This corresponds to a Fujita scale tornado of F3 or greater (a strong tornado). However, extreme winds dominate the rotational winds from a tornado and are more likely. This is also true for wind-borne missiles that are more likely than tornado-generated missiles. Therefore, tornadoes are bounded by the analysis for extreme winds.

C-3.3.6 Turbine Missiles

There are no large steam turbines at the Site. Steam is produced by the steam plant and used directly without generating electricity. There is a small gas turbine generator at Building 371 that is used for emergency power. The frequency of this turbine to fail and produce missiles is considered to be very low, particularly considering the limited periods of operation (the turbine is in operation only during testing or loss of normal power situations). Considering the reliability of these turbines and the limited periods of operation, turbine missiles are screened from further analysis.

C-3.3.7 Accidents Requiring Further Analysis

Following this screening analysis, only a limited number of accidents remained for detailed analysis and quantification. To characterize the accidents for purposes of consequence analysis and risk estimates, it was necessary to more completely define the scenarios, calculate their frequency of occurrence (specific to the *Baseline* and *Closure* Cases), and estimate the release characteristics (including the materials release, the magnitude of the release, and various physical and chemical parameters of the release such as the release height and duration).

The following accident scenarios remained for further qualitative or quantitative analysis after completion of the screening analysis for the radiological accidents:

- Fires within the facility
- Explosions within the facility
- Spills/Loss of Confinement within the facility
- Criticalities
- Earthquakes
- Extreme winds and wind-borne missiles
- Aircraft Crashes

The remainder of this appendix further evaluates the accident types that survived the initial screening process and could either be a bounding risk event, or a bounding consequence event from a credible accident that may provide useful insights for comparison of the *Baseline* and *Closure* Cases. There may be scenarios that are predicted to have extremely serious consequences but the probability that it will occur is extremely remote. Conversely, an accident with relatively small consequences may be of substantial concern because it is predicted to occur relatively often. That is why the risk of the scenario is considered so that probabilities and consequences are appropriately put in perspective.

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For each radiological accident scenario that survived the screening process presented in Section C-3, an inventory of radioactive material that would be released and could potentially result in health effects to humans was developed for the *Baseline* and *Closure* Cases. The impacts of the inventories were assessed by modeling calculations incorporated into a computer code called MELCOR Accident Consequence Code System (MACCS). The computer modeling code calculated estimated impacts to co-located workers and the general public. The methodology employed to estimate doses and latent cancer fatalities are common to all accident scenarios and is presented next. Section C-5 presents the spectrum of credible accidents and severe accidents beyond the design basis that are considered in this CID to represent the risk for the *Baseline* and *Closure* Cases.

C-4.1 Radiological Accident Analysis Methodology

Calculations were performed to estimate the resultant impacts to workers and members of the public for each radiological accident that satisfied the screening criteria. Dose calculations were performed for individuals and collective populations out to 50 miles.

The methodology used to estimate the consequences of radiological accidents is based on current practice for DOE Environmental Impact Statements. MACCS has been used for accident analysis in several environmental impact statements.

When radiation exposures occur, human health may be adversely affected. The possible human health effects from radiation are commonly divided into two categories: deterministic and stochastic.

Deterministic effects are defined as those types of health effects that can result from high radiation doses, incurred at high dose rates, typically under the conditions possible after a severe accident at a commercial power reactor. In general, deterministic effects are defined as having a threshold dose below which the risk of the effect is zero, as well as having a non-linear dose-response function. Sensitivity to deterministic effects, for example, prodromal vomiting and hematopoietic (bone marrow) syndrome, are commonly stated in terms of a LD_{50} (i.e., the dose at which 50% of an exposed population would manifest the health effect).

Deterministic health effects are not assessed in the present study because exposures of the public and co-located workers to weapons-grade plutonium would always result in doses below the thresholds for incurring deterministic effects. This is because the inhalation dose from inhaled plutonium would be incurred over subsequent decades, at a low dose rate.

Stochastic effects from radiation exposure include fatal and non-fatal latent cancers among the exposed population, as well as severe genetic abnormalities among descendants of the exposed population. Stochastic effect risk factors defined by International Commission on Radiological Protection Publication 60 (ICRP 1991b) have been utilized, as recommended by DOE for NEPA risk assessments (DOE 1993e). These risk factors are 5×10^{-4} per rem total effective dose for members of the public and 4×10^{-4} per rem total effective dose for adult workers. The estimates obtained for effects are for fatal cancers.

These cancer risk factors based on whole body exposures are more conservative than those based on organ-specific cancers. The International Commission on Radiological Protection Publication 60 risk factors were developed primarily for the purpose of assessing risks from low Linear Energy Transfer radiation and not the high Linear Energy Transfer radiation that can be incurred from inhalation of weapons-grade plutonium.[9] The fact that high Linear Energy

[9]Linear Energy Transfer, a measurement that is used to help determine the degree or depth of biological damage that may be

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Transfer radiation, per absorbed dose, is more damaging than low Linear Energy Transfer radiation is accounted for through the use of a Quality Factor of 20 for the high Linear Energy Transfer portion of the absorbed dose.

Cancer risk factors developed specifically for high Linear Energy Transfer radiation can be obtained from *Health Effects Models for Nuclear Power Plant Accident Consequence Analysis* (Abrahamson 1993), which provides organ-specific fatal cancer risk factors for bone surface, lung, and liver. The standard guidance for the code calculations at the Site (EG&G 1993n and 1994cc) has assessed the differences in risk estimates obtained using the International Commission on Radiological Protection Publication 60 and Abrahamson risk factors for weapons-grade plutonium. In that assessment it was determined that the use of Abrahamson risk factors is preferable for the assessment of plutonium accidents, because International Commission on Radiological Protection Publication 60 is focused on low Linear Energy Transfer radiation. However, it was also concluded that the International Commission on Radiological Protection Publication 60 fatal cancer risk factor of 5×10^{-4} per rem total effective dose is conservative, yielding an estimate roughly 75% higher than that obtained using the Abrahamson risk factors for plutonium Class Y solubility.

Environmental impacts are presented in terms of human health effects to workers and the public from radiological releases under typical meteorological conditions (e.g., 50th percentile or median) to provide realistic estimates of risks for risk management purposes. Previous quantitative analyses of radiological consequences have been completed using a variety of methodologies and assumptions (e.g., typical versus worst case dispersion assumptions). To standardize these previous accident analyses for comparison purposes, the amount of plutonium released inside the facilities and subsequently to the atmosphere [referred to as the initial source term (IST) and building source term (BST), respectively] is used to estimate radiological consequences to co-located workers and the public using methods presented in this CID assessment.

The consequences from a plutonium release are quantitatively estimated as radiological dose to an on-site or off-site individual, or latent cancer fatalities (LCFs) in the surrounding population. Plutonium must be in a dispersible form and released in multiple gram quantities in order to result in a substantial consequence to a member of the public. As bulk metal reacts or corrodes into an oxide or compound, it turns into dispersible powder, a small fraction of which becomes airborne during an accident. For a release of plutonium to occur in the immediate work area, the primary confinement system (e.g., glovebox, tank, container packaging configuration) must fail. Unless the accident is severe enough to overcome secondary confinement systems (e.g., the building nuclear ventilation and filtration system), the airborne fraction is reduced by several stages of HEPA filtration, which substantially reduces the public consequences from operational accidents within the buildings.

To evaluate potential consequences from radioactive releases at RFETS, the amount of material (usually plutonium) made airborne (called a source term) by an accident is estimated. This source term is then converted into a concentration in air that an individual could be exposed to. Based on a duration of exposure and current dose assessment methodology, a radiological dose commitment or estimate of latent cancer fatalities to an individual or population can be made.

C-4.1.1 Accident Source Term

The methodology to assess the source term from an accident is based on the following model (Mishima 1994; EG&G 1994w):

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imparted to tissue by radiation types. A 250 keV x-ray is considered to have a Linear Energy Transfer of 2 keV/micron (track average), while 14 MeV (14,000 keV) neutron has an Linear Energy Transfer of 12 keV/micron (Hall 1978).

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$$IST = MAR * DR * ARF * RF$$

and $$BST = IST * LPF$$

where:

IST	=	Initial Source Term
MAR	=	Material-at-Risk
DR	=	Damage Ratio
ARF	=	Airborne Release Fraction
RF	=	Respirable Fraction
BST	=	Building Source Term
LPF	=	Leakpath Factor

Material-at-Risk (MAR)

Material-at-Risk (MAR) is the quantity of radioactive material involved in the accident that contributes to the release. Some inventories in the facility may not be involved in the particular accident being analyzed; e.g., a room fire may be evaluated based on only the inventories in a particular fire zone. On the other hand, an event such as seismic collapse of the structure can impact most of the inventory in the building unless it can be demonstrated that the material is not at risk due to protection afforded by rugged packages or vault design.

Recently, DOE released unclassified information on inventories of plutonium (Pu), residues and TRU waste, and enriched uranium at RFETS. In 1993, the Site's accountable inventory was 12.9 metric ton (MT[10]) of weapons grade Pu, in the form of 3.2 MT Pu oxide, 6.6 MT Pu metal, and 3.1 MT Pu residues and Transuranic (TRU) wastes, and 6.7 MT of enriched uranium (DOE 1993i; DOE 1994y; DOE 1996g). Chapter 2 of this CID presents the current Site inventory of 12.7 MT Pu and its distribution by building that were used for the *baseline* case risk assessment. In addition, approximately 300 kg of Pu holdup are estimated in untoward areas in all Pu buildings, and an additional 300 kg Pu are expected to be encountered as residues are processed and assayed with more sensitive instruments (DOE 1994y; EG&G 1994ff). The CID assessment also included an estimated 40 kg of americium in plutonium residues for consideration of impacts to the workers, public, and environment.

The metal inventory includes both solid pieces (such as buttons, ingots, parts) and completed assemblies called pits. The Site is working on plans to ship these pits to the Pantex Plant where they originated during retirement of nuclear weapons. Due to their design, pits do not have dispersible surface contamination and are typically stored in formerly-approved Department of Transportation (DOT) Type B shipping packages. Materials in Type B shipping packages generally have not been included as MAR unless the scenario justifies accident conditions that can fail the package's design basis accident requirements (e.g., 30 minute fire and 30-foot drop test) (DOE 1992p; EG&G 1994bb; and FSARs 1980s). These packages are not expected to be breached by a seismic collapse of the building, as discussed later.

Metal pieces, however, may have a significant coating of dispersible corrosion products that are potentially pyrophoric. Corrosion rates can vary significantly, depending on many factors such as alloyed/unalloyed metal, degree of inert atmosphere during storage, package design, seal integrity, presence of plastics or moisture, etc. Currently, this material must be periodically inspected, brushed, repacked, and any removed corrosion products (oxide, hydride, metal flakes) must be thermally stabilized. Once the metal is repacked into two stainless steel containers with welded lids and inert atmospheres per DOE Standard 3013, *Criteria for Safe Storage of Plutonium Metals and Oxides* (DOE 1994x), there should be no significant accumulation of dispersible surface contamination.

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[10] One metric ton (MT) = 1 million grams (g) = 1,000 kilograms (kg) = 2,200 pounds (lb) = 1.1 English tons.

The 300 kg Pu holdup estimate for the six Pu buildings was based on previous unreviewed safety question determinations for Buildings 371, 707, and 771. DOE informed the public that RFETS has an inventory difference (i.e., amount received less amount shipped plus amount on-hand per accounting records) of approximately 1.2 MT Pu over its 40-year mission (DOE 1994y). An assessment of this inventory difference (EG&G 1994ff) concludes that most of it is due to accounting errors because of the measurement or assay techniques available at the time when TRU waste shipped offsite. Between 1953 to 1971, an estimated 600 to 800 kg may have been shipped to the Idaho National Engineering Laboratory as TRU waste, and perhaps 200 to 300 kg are still at RFETS in residues which will be again assayed with improved instrumentation after the material is repacked or stabilized. The remaining amount on the order of 200 to 300 kg is expected to be held up in untoward areas such as process equipment, gloveboxes, ventilation ductwork, piping, and tanks. For this CID risk assessment, an "at-risk" adjustment equal to 10% was applied to holdup estimates to reflect what is dispersible instead of the total quantity trapped deep within equipment or otherwise tightly fixed to the host (e.g., ductwork, gloveboxes, equipment, etc.). The 10% estimate is an equivalent value based on the three unreviewed safety question determinations for Buildings 371, 707, and 771 which applied two different release estimates for dispersible versus fixed holdup; rather than a single value for dispersible holdup as used in the Defense Nuclear Facilities Safety Board (DNFSB) Recommendation 94-3 Implementation Plan Task 9 risk assessment (DOE 1995jj). For non-impact scenarios, e.g., room fires, this 10% at-risk adjustment would not be appropriate, as all of the MAR would be at risk and contribute to releases.

Damage Ratio (DR)

A damage ratio (DR) is the fraction of the MAR that is impacted by the accident being analyzed. For example, a seismic event that does not collapse the building would not be expected to cause all gloveboxes, tanks, and storage containers to fail and release radioactive material to the environment.

For this assessment, a DR of 1.0 was assumed for seismic collapse scenarios. For those storage situations where the inventory is not at-risk, e.g., DOT Type B equivalent packages not breached by the accident being evaluated, a DR = 0 was applied.

Airborne Release Fraction (ARF)

The airborne release fraction (ARF) is the portion of the MAR (times DR) that is suspended in air by the accident as an aerosol and thus available for transport. The release fractions depend significantly on the physical form of the material and the stresses produced by the particular accident phenomenon, e.g., thermal stress from a fire, impaction by collapsing structure, free fall spill of powders or solutions, etc. In general, material at risk that is in particulate form (such as oxides) have a higher release fraction than solid metals or liquids.

This CID assessment reproduced previous risk assessments that assumed a variety of ARFs and RFs for accident scenarios without adjustments to the current recommendations in the DOE-HDBK-3010-94 handbook, *Airborne Release Fractions/Rates and Respirable Fractions for Non-Reactor Nuclear Facilities* (Mishima 1994). The current recommendations are based on experiments by national laboratories and industry practices applied at DOE and Nuclear Regulatory Commission (NRC) non-reactor nuclear facilities. For any scenario where a new source term was derived for this CID assessment, they are based on the current recommendations and presented in this section or later with the scenario description. General release fractions assumed for the seismic collapse scenario analyzed in this assessment are provided in the next section on respirable fractions.

All radiological source terms consist of weapons-grade plutonium, or variations such as allowing for full in-growth of americium, or accounting for high-americium in plutonium residues. An exception to plutonium releases is for criticality source terms which is discussed later. All plutonium releases are based on compositions for these categories of plutonium as specified in the Site's standardized application of the MACCS code results (EG&G 1993n; EG&G 1994cc; and Kaiser-Hill 1996e).

Respirable Fraction (RF)

The respirable fraction (RF)is that portion of airborne particulates that can be transported through air and inhaled into the human respiratory system and is commonly assumed to include particles 10 microns (µm) Aerodynamic Equivalent Diameter (AED)[11] in size and less (i.e., inhalable particles). The RF is of interest for dose assessments because it is what stays in the lung and can be transported to other organs to result in a radiological dose commitment. It is also the size of particles in a plume that can travel long distances from the release point to expose greater populations.

Unless the accident can impart energies to reduce the original particle size of the MAR, the product of ARF*RF cannot exceed the respirable fraction of the original MAR (Mishima 1994). For example, if the respirable fraction of calcined oxide from a plutonium nitrate solution has been determined by analyzing samples to be 1E-5, and the accident analysis handbook recommendation is an ARF of 1E-3 with an RF = 1E-1 (i.e., for oxide in a container), then the ARF*RF that should be used to estimate the source term is 1E-5 rather than 1E-4.

For seismic collapse scenarios, an ARF*RF = 1E-4 (i.e., 1E-3*0.1) is applied for oxide in sealed storage containers breached by falling debris (Mishima 1994). For oxide stored outside gloveboxes at RFETS, there are a minimum of two sealed containers and two plastic contamination control bags. Plutonium oxide that is exposed within gloveboxes during a seismic collapse of the building experiences three release effects and has an ARF*RF of 2.7E-3 (i.e., sum of 1E-3*0.1 + 2E-3*0.3 + 1E-2*0.2). These effects include a shock-vibration of bulk powder, free-fall spill as the glovebox structure in the free-fall zone collapses, and air turbulence generated by the impact of debris (Mishima 1994). For liquids, the ARF*RF is 4E-5 (all respirable). Dispersible holdup in gloveboxes, ductwork, piping, and tanks have an ARF*RF = 1E-3 (i.e., 1E-3*1.0) because it is assumed all respirable and a 10% "at-risk" adjustment as discussed earlier was applied to the total holdup MAR estimate. For solidified residues, another factor of 10 was applied to reduce the ARF*RF to 1E-5, as was assumed for the DNFSB Recommendation 94-3 Implementation Plan Task 9 risk assessment (DOE 1995jj).

Initial Source Term (IST)

The initial source term (IST) is the airborne amount of radioactive material that is released from the MAR's confinement barriers into the immediate work environment. The IST is used to assess radiological consequences to facility workers, and to estimate the amount released to the environment, as discussed in the following section.

Leakpath Factor (LPF)

A leakpath factor (LPF) is applied to the IST to estimate the quantity of radioactive material released to the atmosphere. It is a measure of the building's safety related structures and systems to mitigate accidents to protect the public and environment. For particulate releases such as from plutonium, the LPF is based on the effectiveness of high efficiency particulate air (HEPA) filters to capture particulates and reduce the IST. If the exhaust HEPA filtration system is not damaged by the postulated accident, a LPF of 1E-3 (i.e., 99.9% efficiency) for the first stage and 2E-3 (i.e., 99.8% efficiency) for subsequent stages is generally recommended if these stages are initially tested to 99.95% efficiency during installation (EG&G 1994w) and periodically re-tested

[11]Note: For Pu dioxide powder, the geometric or mass median diameter (MMD) as determined from analytical techniques is about a factor of 3 less than the AED (i.e, 3 µmMMD is about the same as 10 µmAED) (Mishima 1994).

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per Operational Safety Requirements or Technical Safety Requirements. Larger particles are captured with greater efficiencies than respirable particles, but this is usually not credited in the accident analysis (i.e., the particle size for HEPA filter releases is assumed to be 1 µm for dispersion calculations).

For those events that either can breach the exhaust filtration system, such as a fire due to failure of the plenum's automatic suppression system or an explosion, or can otherwise breach the facility structure such as an earthquake or explosion, a LPF = 1.0 is generally assumed. An exception to this is if the postulated scenario can justify any reduction of the IST, based on the accident phenomenology (e.g., computer modeling of deposition within the building).

The DOE DP Safety Survey (DOE 1993h), FSARs for Rocky Flats Pu facilities (FSARs 1980s), and the environmental assessment for SNM consolidation (DOE 1995l; EG&G 1995j) assumed a LPF = 1E-2 for seismic evaluations of buildings that did not collapse and had no active HEPA filtration and no breaches of exterior walls and roof (i.e., giving some credit for passive confinement). A further refinement of LPFs for different areas of Building 371 for fire and non-fire releases is being considered in the development of the Building 371 BIO (Kaiser-Hill 1996f). These results indicate that the LPF can be reduced for non-fire scenarios and increased for fire scenarios, depending on locations within the building.

For a seismic rubble scenario, the DOE DP Safety Survey developed a first-order approximation of LPFs that generally would reduce respirable releases by 30% to 40% for a structure the size of most RFETS Pu buildings; however, their sensitivity analysis of seismic collapse of buildings did not credit any LPF reduction. For this assessment of the *Baseline* Case and the *Closure* Case, no credit for plateout is given (i.e., LPF=1.0) to those scenarios involving seismic collapse.

Credit can also be taken for deposition and other removal mechanisms as the aerosol transports through the facility. This is usually determined by computer modeling. For this assessment, no credit will be taken for plateout within the facility.

Building Source Term (BST)

The building source term (BST) is the product of all of the IST and LPF, and is used as input to a dispersion model to assess consequences away from the release point. To assess radiological impacts to people, the dispersion analysis is based on the respirable release amount (i.e., < 10 µm AED). For environmental impacts in terms of environmental contamination and cleanup costs, the dispersion analysis should be based on the total airborne release since larger particles can transport some distance away from the release point, and these particles can also weather over time and be resuspended. This consideration applies only to those scenarios that do not credit HEPA filtration. For this CID risk assessment, impacts to the environment are considered in terms of impact to people, rather than environmental contamination and cleanup costs.

The MACCS code also requires the release height and release duration for each source term. Release durations were generally modeled as a 10-minute release, a code limitation for the shortest release. A longer release duration could be modeled which would lower estimates for the maximally exposed off-site individual, but not for the 50-mile population. The release heights were assumed to be ground level releases which results in additional conservatism, instead of using the actual building or stack height. For example, the seismic events and high wind scenarios that result in building collapse or substantial structural damage were estimated to have a 3-meter release height based on the judgment that this would represent the height of the collapsed building debris. For major fires, 6 megawatts were assumed which allowed the MACCS code to calculate an effective release height which would lower consequences to the co-located worker and at the Site boundary for worst case weather conditions; the greatest dose to the maximally exposed off-site individual would be approximately 4 miles where the plume

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touches ground level. For median weather conditions, the 6 megawatt fire does lower the concentration at the Site boundary.

C-4.1.2 Consequence and Risk Models

Once the source term is estimated, the radiological consequences can be evaluated. The methodology varies depending on how the release is dispersed and which receptor is being analyzed. Risk estimates can then be calculated based on the accident's frequency, and summed for all bounding scenarios analyzed to present the composite risk from a facility or the entire site.

Public

The approach used for assessing radiological consequences to the public is based on dispersion and dose assessment methods currently being applied at RFETS. The MELCOR Accident Consequence Code System (MACCS) was applied for Pu releases (Chanin 1990a and 1990b). Two public receptors are of interest: a hypothetical maximally exposed off-site individual (MOI) at the site boundary (or greater distance for lofted plumes), and approximately 2 million people within 50 miles of the Site.

Maximally Exposed Off-site Individual

The RFETS dispersion analysis for the maximally exposed off-site individual (MOI) is based on the MACCS statistical analysis of hourly meteorological data for a one year period for the minimum site boundary of 1.9 km from the center of the plutonium buildings (the actual distance from each Pu building would not significantly change results for this risk assessment of the relative differences between *Baseline* and *Closure* cases, but could be important for radiological citing purposes to establish an authorization basis). For accident analysis purposes in this assessment, a median atmospheric dispersion factor is assumed to provide a realistic estimate of consequences (and risk), and is equivalent to a stability category D with 4.5 m/sec wind speed meteorological condition (EG&G 1993n). The MOI is assumed to remain in the plume centerline for the duration of plume passage and afterward. This approach is consistent with the Site's approach for hazards and accident analysis being used for development of BIO documents (Kaiser-Hill 1996e). The MOI atmospheric dispersion factor (X/Q) is 1.05E-5 sec/m^3 for median dispersion (and 1.02E-4 sec/m^3 for worst case 95th percentile dispersion), which is based on no depletion of the plume (i.e., deposition velocity = 0).

For estimates of a 50 year committed dose to the MOI, a unit conversion factor of 0.115 rem (CEDE)/g Pu respirable BST is used for Class Y Pu (or 1.1 rem/g Pu respirable BST for worst case dispersion). This is based on a breathing rate of 3.6E-4 m^3/sec (heavy activity) and dose conversion factors for aged weapons grade Pu from the MACCS code equivalent to 3.03E+7 rem/g Pu inhaled (Class Y) (Kaiser-Hill 1996e; EG&G 1994cc). Assuming aged weapons grade plutonium accounts for maximum americium-241 ingrowth with corresponding depletion of the plutonium-241, resulting in a dose conversion factor that is approximately 9% higher than weapons grade Pu. For a lofted fire, the MOI unit dose conversion factor for median weather is 0.027 rem (CEDE)/g Pu BST for Class Y aged Pu (or 0.11 rem (CEDE)/g Pu BST for worst case dispersion).

If a scenario involves high americium residues (e.g., molten salts), then the dose conversion factor is 1.92E+8 rem/g Pu inhaled (Kaiser-Hill 1996e). This is approximately 6.3 times aged weapons grade Pu and 6.9 times higher than weapons grade Pu.

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To account for pure americium releases, the dose conversion factor is approximately a factor of 66[12] times higher than solubility Class Y weapons grade Pu.

For enriched uranium and depleted uranium, the dose conversion factors are much less than for plutonium and do not add substantially to public impacts (Kaiser-Hill 1996e).

Risk to the MOI is calculated by the product of the expected dose to the MOI times the accident frequency. The units of MOI risk are rem(CEDE)/yr; this value is useful for comparing *Baseline* and *Closure* cases to show their relative difference. There is no risk acceptance criterion recommended by DOE for comparing the absolute value of MOI risk. The absolute value of dose when estimated with worst case dispersion conditions, however, can be compared to radiological citing criteria (e.g., 25 rem), or accident evaluation guidelines which may be established to designate safety class structures, systems, and components.

Population

The RFETS dispersion analysis for the approximately 2.2 million population within 50 miles is based on the MACCS statistical analysis of hourly meteorological data for a one year period.

For estimates of the number of LCFs within the population, a unit conversion factor of 1.53E-2 LCF/g Pu respirable BST for Class Y Pu, regardless of whether or not the release is lofted by a fire (EG&G 1994cc). For high-americium residues, this was increased by the factor of 6.3 as discussed earlier for the MOI. The cancer unit conversion factor is based on the dose assessment methodology used for the MOI calculation, except with a breathing rate of 3.3E-4 m^3/sec, the higher aged weapons grade Pu dose conversion factor, and a stochastic cancer risk factor of 5E-4 LCF/rem (CEDE). The cancer risk factor is from the DOE guidance document for preparing environmental assessments and environmental impact statements (DOE 1993e) and is higher by a factor of 1.75 for Class Y and 6.5 for Class W than the critical organs approach recommended for RFETS accident analyses which is based on the ITRI method (EG&G 1993n and 1994cc). The higher cancer risk factor is consistent with the value used for the DOE DP Safety Survey (DOE 1993h).

Although it is conservative to not credit deposition for assessing dose to the MOI at the site boundary, the opposite is true for population dose and LCF estimates. This is due to how the MACCS model evaluates early versus chronic exposures (i.e., resuspension becomes very important), and how it combines the results from many different weather scenarios (EG&G 1993n). Therefore, the unit LCF conversion factor used in this assessment for the population within 50 miles is based on some depletion of the plume, as recommended for RFETS accident analysis (EG&G 1993e and 1994cc) based on an "unknown" particle size distribution (which is almost equivalent to 0.1 cm/sec deposition velocity for 1 μm AED particles as shown in Table C-4). The DOE DP Safety Survey was based on 1.0 cm/sec deposition velocity which is generally associated with 10 mm AED particles. The impact of using no deposition, 0.1 cm/sec, and 1.0 cm/sec for mean and 95th percentile meteorology and weapons grade Pu is shown in Table C-4. The LCF estimates provided in this assessment can be scaled to these assumptions by rationing the values in Table C-4 to the Class Y 1.53E-2/g Pu BST unit conversion factors.

[12] This factor is being used for current safety analyses authorization basis evaluations and is higher than the previously reported factor of 35 that was documented in the Fourth Maximum Credible Accident/Emergency Planning Zone Review (EG&G 1992i). The technical basis for the factor of 66 is being documented in a replacement to Kaiser-Hill 1996e BIO/BFO Dose Template.

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Table C-4. Deposition Impacts on Latent Cancer Fatality Estimates

Dispersion Condition	Population Unit LCF Factor Per Gram Pu (Class Y) Released		
	No Deposition	0.1 cm/sec Deposition Velocity	1.0 cm/sec Deposition Velocity
Median	1.07E-2	1.28E-2	2.71E-2
Mean	2.99E-2	4.06E-2	6.37E-2
95th percentile	1.48E-1	1.87E-1	2.59E-1

Risk to the population is calculated by the product of the expected number of LCFs times the accident frequency. The units of population risk are LCF/yr; this value is useful for comparing the *Baseline* and *Closure* Cases to show their relative difference.

Co-located Workers

To assess consequences to the co-located worker, one or more locations away from the facility where the release occurs is chosen. The location could be the nearest adjacent building, all buildings at RFETS with or without population weighting, or a specified distance to a hypothetical maximum exposed individual. The last approach is chosen for this assessment, i.e., a distance of 100 m to an unprotected worker outside a facility. This is consistent with the BIO approach and previous safety analyses at RFETS and some other DOE sites. This results in a median atmospheric dispersion factor of 1.29E-3 sec/m^3 (or 1.05E-2 sec/m^3 for 95th percentile) (Kaiser-Hill 1996e; EG&G 1993n and 1994cc), which is approximately a factor of 100 higher than for the MOI at the site boundary. All other assumptions for calculating dose are the same as for the MOI. This results in a unit conversion factor for median weather of 14 rem (CEDE)/g Pu BST for Class Y aged Pu (or 114 rem (CEDE)/g Pu BST for worst case dispersion). For a lofted fire, the co-located worker unit dose conversion factor for median weather is 9.2E-3 rem (CEDE)/g Pu BST for Class Y aged Pu (or 3.9 rem (CEDE)/g Pu BST for worst case dispersion). For high-americium residues, this was increased by the factor of 6.3 as discussed earlier for the MOI.

Risk to the co-located worker is calculated by the product of the expected dose times the accident frequency. The units of co-located worker risk are rem(CEDE)/yr; this value is useful for comparing *Baseline* and *Closure* cases to show their relative difference. There is no risk acceptance criterion recommended by DOE for comparing the absolute value of co-located worker risk. The absolute value of dose, however, can be compared to accident evaluation guidelines which may or may not be established (see discussion in Section C-5 on the new facility alternatives).

For a more comprehensive discussion of the MACCS model and assumptions used for this analysis, see the technical support document for the Building 371 *SNM Consolidation EA* (EG&G 1995j), and the Site's technical support documents developed to standardize use of the model (EG&G 1993n and 1994cc).

Facility Worker

Previous safety analyses for FSARs and NEPA EAs at RFETS have quantitatively evaluated radiological consequences and risk to the facility workers. However, recent DOE guidance recommends a qualitative assessment due to the large uncertainties regarding dispersion within the workplace and evacuation times (DOE 1994w). This is the approach

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used for the Savannah River Site Interim Management of Nuclear Materials EIS (DOE 1995gg) and the draft Storage and Disposition PEIS (DOE 1996b).

C-5 Radiological Accident Scenarios

For the seven accident categories that survived the screening process in Section C-3, a spectrum of bounding accidents were developed. The analyses that follow are borrowed and/or updated from numerous previous risk assessments or accident analyses. References to the original evaluation appear initially for each accident discussion, and again where specific results (e.g., estimates of accident frequency or source terms) were used for this CID assessment. A summary of the scenario is first presented for the *Baseline* Case, and if necessary, it is followed by a discussion of how the scenario could be different for the *Closure* Case. For further information regarding specific assumptions such as success or failure of credited controls, material-at-risk, release fractions, leakpath factors, etc., the original assessment should be consulted. The scenario summary includes a brief description of the type of accident and its causes, its frequency of occurrence estimate, and the magnitude of the source term released to the environment. Based on the CID dispersion analysis, information on consequences (dose or latent cancer fatalities) and risk estimates for the co-located worker, maximally exposed off-site individual, and population is presented in a summary table for each category of accidents evaluated, rather than with the scenario summary.

For the *Closure* Case, several assumptions were made. First, that the existing level of protection will continue to be implemented to protect the workers, co-located workers, and public such that future risks would continue at no higher than those presented for the *Baseline* Case, unless they were specifically evaluated for the *Closure* Case (e.g., residue stabilization and repackaging activities). Second, future DD&D activities would be sufficiently controlled by appropriate authorization basis documents (e.g., Operational/Technical Safety Requirements, Unreviewed Safety Question Determinations, Basis for Interim Operations, Basis for Operations, DD&D SARs or auditable safety analyses, etc.) such that their risks would be less than or no greater than those associated with current *Baseline* risks.

Third, construction of several new facilities that are proposed to be built for storage of plutonium or TRU waste will be per appropriate design criteria for nuclear or radiological facilities. For the new Plutonium Interim Storage Vault, a very important safety analysis assumption is that this new facility will be designed to current DOE requirements for a nonreactor nuclear facility (e.g., equivalent to the general design criteria in DOE Order 6430.1A, or its successors such as Order O420.1), and operated per the 10 CFR 830-series on nuclear safety management rules to be published. This would eliminate releases from potential externally-initiated design basis accidents such as natural phenomena (i.e., by designing to DOE Standard 1020 Performance Category 4), other on-site external hazards, and aircraft crashes. However, the residual risk from severe accidents beyond the design basis and those that were determined to be not credible (i.e., a frequency of occurrence less than 1×10^{-6} per year) is evaluated in this CID.

For a new storage facility at RFETS, or any other location, certain regulatory requirements must be satisfied. These include limiting releases from the facility due to normal operations or postulated accidents to protect co-located workers, the public, and the environment, as well as providing for the safety of facility workers.

The Clean Air Act regulation (40 CFR 61Hb) requires that annual emissions must not exceed 10 mrem to any individual off-site. This limit applies to all emissions from the site, not one individual facility or building. It also was established for routine emissions from normal operations, and only applies to accident emissions if they occur, not when they are predicted using risk assessment techniques. However, most accident risks can be managed below this limit

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depending on what commitments are made in the facility's Technical Safety Requirements (TSRs) for engineering and administrative controls.

A number of risk-based criteria for design or evaluation of nuclear facilities have been proposed over the years. These criteria attempt to combine the probability and consequences of accidents to the public in a way that no single event exceeds some specified target goal (i.e., the accident data point should be well below the risk criteria or risk curve). These were not intended as risk acceptance criteria, but rather as design and evaluation guidelines so that risks can be managed As Low As Reasonably Achievable (ALARA). A summary of several recommended schemes for nuclear reactor and non-reactors was provided in a draft report, *General Safety Guidelines For the Design of High-Hazard (Non-Reactor) Facilities at Rocky Flats Plant* (Rockwell 1989). Most of these schemes were based on the 25 rem (CEDE) radiological citing criterion for low probability events (i.e., > 1 x 10^{-6}/yr) and some of them were scaled to annual normal operations limits (e.g., 10 or 100 mrem/yr) for high probability events (e.g., in the range of 1 x 10^{-2} to 1/yr). The draft Rocky Flats guidelines and the DOE *Non-Reactor Nuclear Facilities: Standards and Criteria Guide* (Brookhaven 1986) are based on NRC's guidance for a design objective of 5 mrem/yr at a frequency of occurrence of 1 per plant year (10 CFR 50I). This results in a constant MOI risk estimate of 5E-3 rem/yr that bounds most of the recommended criteria, and which is a factor of 2 less than the 10 mrem/yr Clean Air Act limit.

Evaluation guidelines for upgrading safety analysis reports for existing facilities, or for SARs for new facilities, have not yet been issued by DOE. Several values have been proposed in a draft DOE Standard 3005 (DOE 1994v) which was most recently canceled and replaced by a draft appendix (DOE 1995ff) to DOE Standard 3009 (DOE 1994w). The draft DOE Standard 3005 values were in general agreement with those described above (e.g., 25 rem @ 1E-6/yr and 0.5 rem @ 1E-1/yr), but the latest recommendation only relies on the 25 rem criterion regardless of likelihood.

In summary, a new passive storage facility must be designed and operated such that routine emissions from normal operations are less than the Clean Air Act limit (i.e., 10 mrem/yr). The Site's experience has been that routine emissions are much less than 1 mrem/yr due to sufficient controls (e.g., HEPA filtration). Considering accident risks, with sufficient TSR controls (e.g., design features such as engineered controls, maintenance of an adequate distance to the site boundary, and TSR administrative controls), the facility can be designed and operated to the industry recommendations for accident evaluation guidelines.

C-5.1 Radiological Fires

Numerous fire scenarios have been analyzed by previous NEPA, safety analysis, and emergency preparedness documents. The following fire scenarios were determined to dominate the estimate of fire risk for the Site, and are further evaluated:

- A fire initiated inside glovebox operations.
- A fire initiated inside a plutonium processing area involving either gloveboxes or drums of residues in storage.
- A plutonium pit fire inside a storage drum or vault.
- A large fire in a plutonium storage vault was screened out as not credible accident, but was evaluated as a low probability severe accident that was analyzed to provide additional perspectives on residual risks being accepted.
- A fire on a plutonium building's shipping dock involving plutonium metal or oxide, potentially pyrophoric forms of plutonium, plutonium residues or TRU wastes, or high-americium plutonium residues.

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- A fire in a TRU waste or low level waste (LLW) storage building (initiated either by spontaneous combustion of combustibles within a storage package or by an external fire source within the storage area)

C-5.1.1 Fire Inside Gloveboxes

The Site has a history of fires initiated inside gloveboxes involving plutonium. Previous risk assessments have demonstrated that due to fire protection systems and HEPA filtration, the source term, radiological consequences, and risks would be very low. The bounding glovebox fire was determined to be associated with bypass of the HEPA filters. This scenario was evaluated for resumption of plutonium operations in Building 707 (SWEC 1991; SWEC 1992) and updated for the *SNM Consolidation EA (DOE 1995l)*. This scenario is a "station blackout" in which all electrical power is lost. Considering the failure of redundant off-site power sources and the buildings emergency diesel generator, the frequency of this event was assessed to be 6 x 10^{-5}/yr (DOE 1995l). The *SNM Consolidation EA* determined a source term of 1 x 10^{-1} g Pu (DOE 1995l).

Consequences (dose and latent cancer fatalities) and risks to the co-located worker, maximally exposed off-site individual, and 50-mile populations from this fire initiated inside gloveboxes are presented in Table C-5. An example of how to interpret that data is that based on the estimated source term and the CID dispersion analysis, it could result in a dose of 1.4 x 10^{0} rem CEDE to the co-located worker, 1.1 x 10^{-2} rem CEDE to the MOI, and 1.5 x 10^{-3} latent cancer fatalities to the population. Based on these consequences and the estimated accident frequency, risks would be 8.4 x 10^{-5} rem/yr to the co-located worker, 6.9 x 10^{-7} rem/yr to the MOI, and 9.2 x 10^{-8} LCF/yr to the population. These estimates of risks are used to determine their risk-significance to the overall composite risk from all accidents evaluated, and for comparison between the *Baseline* Case and the *Closure* Case.

Table C-5. Fire Risk for *Baseline* Case

			Maximally Exposed Off-site Individual		Co-located Worker		Population	
Fire Scenario	**Accident Frequency (per year)**	**Source Term (g Pu)**	**Dose rem**	**Risk rem/yr**	**Dose rem**	**Risk rem/yr**	**Conseq LCF**	**Risk LCF/yr**
Inside Glovebox fire	6.0E-5	1.0E-1	1.1E-2	6.9E-7	1.4E+0	8.4E-5	1.5E-3	9.2E-8
Metal sizing								
Room - Pu processing	2.0E-7	4.0E-2	4.6E-3	9.2E-10	5.6E-1	1.1E-7	6.1E-4	1.2E-10
Room - residues	8.0E-6	2.2E-6	1.6E-6	1.3E-11	2.0E-4	1.6E-9	2.1E-7	1.7E-12
Pit fire	1.0E-4	1.5E-6	1.7E-7	1.7E-11	2.1E-5	2.1E-9	2.3E-8	2.3E-12
SNM vault fire	4.0E-7	1.0E+2	2.7E+0	1.1E-6	9.2E-1	3.7E-7	1.5E+0	6.1E-7
Dock - oxide & metal	2.0E-6	1.3E-1	1.5E-2	3.0E-8	1.8E+0	3.7E-6	2.0E-3	4.0E-9
Dock - pyrophoric	2.0E-6	2.5E-2	2.9E-3	5.7E-9	3.5E-1	7.0E-7	3.8E-4	7.7E-10
Dock - residues	2.0E-6	5.4E-1	6.2E-2	1.2E-7	7.6E+0	1.5E-5	8.3E-3	1.7E-8
Dock - hi-Am residues	2.0E-6	1.5E-1	1.1E-1	2.2E-7	1.4E+1	2.7E-5	1.5E-2	3.0E-8
Pu bldg dock - TRU waste	2.0E-3	1.0E-1	1.1E-2	2.3E-5	1.4E+0	2.8E-3	1.5E-3	3.1E-6
TRU waste spont. drum fire	3.3E-3	1.0E-1	1.1E-2	3.8E-5	1.4E+0	4.6E-3	1.5E-3	5.1E-6
1 LLW crate	4.5E-2	1.5E-1	1.7E-2	7.7E-4	2.1E+0	9.4E-2	2.3E-3	1.0E-4
15 LLW crates	5.1E-3	2.3E+0	6.0E-2	3.1E-4	2.1E-2	1.1E-4	3.4E-2	1.8E-4
Fire Risk				1.1E-3		1.0E-1		2.9E-4

For the *Closure* Case, a second glovebox fire scenario involving size-reduction of metal for the DOE Standard 3013 container is of interest. The *SNM Consolidation EA (DOE 1995l; EG&G 1995j)* evaluated this scenario and applied the same estimates of frequency and source term as that presented for thermal stabilization. Therefore, the risk for the *Closure* Case is twice that of the *Baseline* Case, as shown on Table C-6. These two potential fires within gloveboxes will be eliminated in the Year 2004 when all SNM and residue stabilization and repackaging is completed, and SNM is stored in the DOE Standard 3013 50-year packaging in the new Plutonium Interim Storage Vault.

Table C-6. Fire Risk for *Closure* Case

			Maximally Exposed Off-site Individual		Co-located Worker		Population	
Fire Scenario	**Accident Frequency (per year)**	**Source Term (g Pu)**	**Dose rem**	**Risk rem/yr**	**Dose rem**	**Risk rem/yr**	**Conseq LCF**	**Risk LCF/yr**
Inside Glovebox fire	6.0E-5	1.0E-1	1.1E-2	6.9E-7	1.4E+0	8.4E-5	1.5E-3	9.2E-8
Metal sizing	6.0E-5	1.0E-1	1.1E-2	6.9E-7	1.4E+0	8.4E-5	1.5E-3	9.2E-8
Room - Pu processing	2.0E-7	4.0E-2	4.6E-3	9.2E-10	5.6E-1	1.1E-7	6.1E-4	1.2E-10
Room - residues	8.0E-6	2.2E-6	1.6E-6	1.3E-11	2.0E-4	1.6E-9	2.1E-7	1.7E-12
Pit fire	1.0E-4	1.5E-6	1.7E-7	1.7E-11	2.1E-5	2.1E-9	2.3E-8	2.3E-12
SNM vault fire	4.0E-7	1.0E+2	2.7E+0	1.1E-6	9.2E-1	3.7E-7	1.5E+0	6.1E-7
Dock - oxide & metal	8.0E-6	1.3E-1	1.5E-2	1.2E-7	1.8E+0	1.5E-5	2.0E-3	1.6E-8
Dock - pyrophoric	2.0E-6	2.5E-2	2.9E-3	5.7E-9	3.5E-1	7.0E-7	3.8E-4	7.7E-10
Dock - residues	8.0E-6	5.4E-1	6.2E-2	4.9E-7	7.6E+0	6.1E-5	8.3E-3	6.6E-8
Dock - hi-Am residues	8.0E-6	1.5E-1	1.1E-1	8.8E-7	1.4E+1	1.1E-4	1.5E-2	1.2E-7
Pu bldg dock - TRU waste	2.0E-3	1.0E-1	1.1E-2	2.3E-5	1.4E+0	2.8E-3	1.5E-3	3.1E-6
TRU waste spont. drum fire	6.6E-3	1.0E-1	1.1E-2	7.6E-5	1.4E+0	9.3E-3	1.5E-3	1.0E-5
1 LLW crate	4.5E-2	1.5E-1	1.7E-2	7.7E-4	2.1E+0	9.4E-2	2.3E-3	1.0E-4
15 LLW crates	5.1E-3	2.3E+0	6.0E-2	3.1E-4	2.1E-2	1.1E-4	3.4E-2	1.8E-4
Fire Risk				1.2E-3		1.1E-1		2.9E-4

C-5.1.2 Fires in Pu Processing Areas

The Site also has a history of fires initiated inside rooms housing plutonium processing operations (e.g., gloveboxes, tanks) or where plutonium residue drums are stored. A bounding fire scenario involving gloveboxes was evaluated for the resumption of plutonium operations in Building 707 (SWEC 1991; SWEC 1992) and updated for the *SNM Consolidation EA (DOE 1995l)*. Assuming failure of the Site's ignition control and combustible control program, and considering the success and failure of fire protection systems and programs, the frequency of this event was assessed to be 2 x 10^{-7}/yr (DOE 1995l). The *SNM Consolidation EA* determined the source term to be 4 x 10^{-2} g Pu (DOE 1995l). Consequences (dose and latent cancer fatalities) and risks to the co-located worker, maximally exposed off-site individual, and 50-mile populations from this fire initiated inside Pu processing areas are presented in Table C-5. For the *Closure* Case, this risk will be eliminated in the Year 2004 when all SNM stabilization and repackaging is completed, and SNM is stored in the DOE Standard 3013 50-packaging in the new Interim Storage Vault.

For potential fires initiated in residue drum storage areas in four buildings (371, 707, 771, 776/777), the frequency of this event was increased to 8 x 10^{-6}/yr for the *Residue Stabilization EA* (DOE 1996c). The source term from high americium plutonium residues was 2.2 x 10^{-6} g Pu (DOE 1996c). Consequences (dose and latent cancer fatalities) and risks to the co-located worker, maximally exposed off-site individual, and 50-mile populations from this fire initiated inside storage areas are presented in Table C-5. For the *Closure* Case, this risk will be eliminated in the Year 2003 when all residue stabilization and repackaging is completed, and material is stored in TRU waste facilities.

C-5.1.3 Pu Pit Fire

Plutonium pits are stored in vaults or vault-type rooms on storage racks or in approved or formerly-approved Department of Transportation (DOT) Type B packages. A plutonium pit fire is possible. There have been reported occurrences within the DOE Complex of pits cracking while in storage. The cracks have been related to severe and rapid temperature changes of the plutonium pit. These events have occurred at the Los Alamos National Laboratory and the Pantex Plant (LLNL 1993). Only a small amount of oxidation localized along the crack has been observed in these cases. Pit package inspection (to ensure their integrity and package temperature) and monitoring of suspect pits (pits of the design observed to crack) allow for mitigating actions to be taken. The draft Basis for Interim Operations for Building 371 credit this control to reduce the likelihood of a plutonium pit fire to an "extremely unlikely" accident (Kaiser-Hill 1996f). For purposes of this CID comparison of the *Baseline* and *Closure* Cases, the higher end of the frequency bin is assigned at a probability of occurrence of $1x10^{-4}$/yr. By crediting two stages of HEPA filtration for pits stored on shelves, the release to the environment would be 1.5×10^{-6} g Pu (Kaiser-Hill 1996f). Consequences (dose and latent cancer fatalities) and risks to the co-located worker, maximally exposed off-site individual, and 50-mile populations from a Pu pit fire are presented in Table C-5. For the *Closure* Case, this risk will be eliminated in the Year 1999 when shipping to the Pantex Site and other DOE national laboratories is completed. If shipping is delayed and pits must be stored in the new Plutonium Interim Storage Vault, its risk will increase by approximately three orders of magnitude due to the less confinement protection (i.e., from the DOT Type B shipping package only) compared to two credited stages of HEPA filters in Building 371.

C-5.1.4 Fire in Pu Storage Vault

SNM is stored in a variety of different configurations at the Site. This includes exposed metal or primary containers in vaults that are part of the Zone I HVAC glovebox system, as well as in multiple containment vessels in Zone II HVAC areas such as vault-type rooms. An example of a Zone I vault is the stacker-retriever in Building 371 for storage of SNM and some forms of residues, or the Building 707 X-Y retriever.

The *SNM Consolidation EA* (DOE 1995l) assumed that extensive fires in vaults are not considered credible (i.e., a frequency of occurrence greater than $1x10^{-6}$/yr). Exposure fires are possible but require ordinary combustible material and an ignition source. Vaults are locked and are not routinely accessed, and combustibles are not permitted. Welding and other ignition sources are prohibited in vaults by procedures unless the SNM is removed or protected. Existing Zone II vaults have fire walls, heat detectors in ducts, and have automatic sprinklers or heat detectors.

Fires due to the pyrophoric properties of plutonium are possible if the Site's procedure on handling and storing these forms are not effectively implemented. This risk was addressed in the *Environmental Assessment for Resumption of Thermal Stabilization of Plutonium Oxide in Building 707* (DOE 1994p; EG&G 1993j). Although a pyrophoric fires could occur in a vault area, it is not expected to propagate to adjacent containers due to heat loss to the surrounding racks and room structures (EG&G 1994bb). Potential releases to the vault would be filtered by HEPA filters, and thus are not a significant risk contributor. For the *Closure* Case, a pyrophoric fire during interim storage is less likely due to the stabilization, repackaging, and surveillance requirements of DOE Standard 3013 (DOE 1994x).

The *SNM Consolidation EA* (DOE 1995l; EG&G 1995j) did analyze a low probability severe accident involving a large fire engulfing a storage vault. Event tree analysis assumptions for this scenario as evaluated in the Building 707 Final Safety Analysis Report (Rockwell 1987b) yielded a probability of occurrence for this series of events of less than $7x10^{-10}$/yr (SWEC 1991). The probability of occurrence is $<<1x10^{-6}$/yr because multiple

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engineered and administrative control system failures are necessary. However, it is conservatively assumed that the probability of occurrence is 1×10^{-7}/yr per plutonium building as used in the draft *Storage and Disposition of Weapons-Usable Fissile Materials Programmatic Environmental Impact Statement* (DOE 1996b). For storage in Buildings 371, 707, 771, and 776/777, the frequency of occurrence of a major vault fire is 4×10^{-7}/yr.

The *SNM Consolidation EA* (DOE 1995l; EG&G 1995j) calculated the release to the environment for a 2 megawatt fire that engulfs 25% of the MAR as 1×10^{2} g plutonium (respirable). This source term is similar to that estimated for the draft *Storage and Disposition of Weapons-Usable Fissile Materials Programmatic Environmental Impact Statement* (DOE 1996b).

Consequences (dose and latent cancer fatalities) and risks to the co-located worker, maximally exposed off-site individual, and 50-mile populations from a major fire in SNM vaults are presented in Table C-5.

For the *Closure* Case, this risk will be reduced as SNM is consolidated into Building 371 (e.g., Building 771 by 1999, and 707 and 776/777 by 2003) by the ratio of the number of plutonium buildings being used to store SNM. When SNM is relocated to the new Plutonium Interim Storage Vault in 2004, the Building 371 risk from vault fires will be reduced by approximately one-fourth because of reductions in the source term discussed next. The risk from vault fires is eliminated after the year 2014 when all material must be shipped off-site[13]

For the new Plutonium Interim Storage Vault, the DNFSB 94-3 Implementation Plan Task 3-2B report (DOE 1995hh) indicated that natural convection can keep stored metals and oxides and other materials below required temperatures for normal operations, and also during upset conditions where air inlets are blocked for up to a week. Also, it could be possible to show that even indefinite loss of cooling would only cause economic damage to the DOE Standard 3013 containers, but not a release (i.e., this assumption relies on can ductility and strain to failure versus phase change loading mechanism). Therefore, there should be no credible accident associated with internal temperature excursions. This thermal analysis should be documented in the PSAR as it is developed.

During normal storage conditions, the ten DOE Standard 3013 containers inside a storage tube are assumed to not be at risk to credible fires because of the design of the storage tube and DOE Standard 3013 containers, coupled with the lack of combustible construction materials needed for the new vault, and lack of possible ignition sources. This assumption should be validated during development of the PSAR during design. The most likely time plutonium would be at risk is during handling of abnormal containers outside of the storage tubes (e.g., inside the portable contamination control cell). However, the probability of occurrence of a fire should be much less than 1×10^{-7}/yr because of engineered fire systems and administrative controls for the contamination control cell. Therefore, it is assumed that one storage tube is involved in a fire during dispositioning of an abnormal container. The probability of occurrence is assumed to be the same as for Building 371, i.e., 1×10^{-7}/yr.

For ten DOE Standard 3013 containers with 4500 g plutonium each (in oxide form) inside a storage tube assumed to be breached by an external fire from transient combustibles, the source term from was calculated to be 2.7×10^{1} g plutonium, based on and ARF of 6×10^{-3} and 10% respirable (DOE 1996s) released inside the facility above the charging deck and released to the environment because no credit is taken for the HEPA filtration system. Table C-6 shows the risk associated with vault fires, which is the same as for the *Baseline* Case during the near

[13] To provide a bounding perspective on risks at the Site, it was assumed that plutonium metal and oxide would not be shipped to the Savannah River Site as early as the year 2004 when their new Actinide Packaging and Storage Facility is scheduled to accept Rocky Flats materials; this material is assumed to be stored on-site until the deadline established in the Rocky Flats Cleanup Agreement.

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term. The consequences and risks from fires in the Interim Storage Vault are approximately 25% of the risks shown on Table C-6.

C-5.1.5 Fire on the Dock

Potential fires on the dock of a plutonium facility could involve plutonium metal or oxide, residues (including high-americium), and TRU waste or LLW generated by the facility. Although residue drum fires would bound any releases from TRU waste and LLW drum fires on the dock, TRU wastes are evaluated separately since their risks will exists until the facilities are DD&D'd. The dock fire can be risk-significant because it could result in an unfiltered release to the environment.

Two general types of packages are of interest in transportation accidents: Type A and Type B packages. Type B packages are designed and tested to withstand relatively stringent conditions (see Appendix A, "Traffic and Transportation"). In contrast, Type A packages do not have these stringent design and test conditions and are therefore much more likely to fail in a vehicle crash and fire. Under most circumstances, a Type B package would fail only if it were improperly sealed and the improper seal were missed during quality assurance inspections prior to shipment. The likelihood of occurrence for this type of quality assurance failure was estimated at 3×10^{-4} per package.[14] Considering the already relatively low frequency of dock fires (of the order of 2×10^{-6} per year as discussed later), multiplying this frequency by the conditional probability of a defective Type B package seal would result in an extremely low frequency (6×10^{-10} per year), which is well below the screening criteria of 1×10^{-6} to 1×10^{-7} per year. Accordingly, dock fires involving Type B packages are not further considered.

The FSAR Review Team (SWEC 1992) estimated the probability of occurrence of a large fire initiated on the dock with doors open to be 2×10^{-6}/yr, based on the expected frequency of handling plutonium oxide, no dock fires occurring during 175 building-years of plutonium operations at RFETS, dock doors open 1% of the time, and assumptions on combustibles and other mitigating circumstances. This scenario could be initiated by welding operations, electrical shorts, or other miscellaneous causes. This scenario has been used for the *Environmental Assessment for Resumption of Thermal Stabilization of Plutonium Oxide in Building 707* (DOE 1994p; EG&G 1993j), the *SNM Consolidation EA* (DOE 1995l; EG&G 1995j), and the *Residue Stabilization EA* (DOE 1996c). This frequency was assumed for each of the following four scenarios evaluated.

The *SNM Consolidation EA* (DOE 1995l; EG&G 1995j) estimated the source term from dock fires involving Pu metal and oxide as 1.3×10^{-1} g Pu, and from potentially pyrophoric forms of Pu as 2.5×10^{-2} g Pu. The *Residue Stabilization EA* (DOE 1996c) estimated the source term from dock fires involving residues as 5.4×10^{-1} g Pu, and from high-americium residues as 1.5×10^{-1} g Pu. Consequences (dose and latent cancer fatalities) and risks to the co-located worker, maximally exposed off-site individual, and 50-mile populations from these four dock fires are presented in Table C-4.

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[14]The only way a Type B package would fail would be for it to be subjected to conditions beyond the certification tests (which is unlikely) or for a severe quality assurance lapse to result in an improperly sealed Type B package. Standard nuclear industry human reliability analysis estimates (NRC 1983c) indicate that the conditional probability of failing to properly mate a connector (such as a package lid) is 3×10^{-3} per demand. The conditional probability of failure of the independent verification is estimated to be 0.1 per demand. Thus, the failure of a Type B package lid to be properly sealed is of the order of 3×10^{-4} per package (this conditional probability cannot be much lower than this; even under very tightly controlled conditions associated with nuclear weapons assembly, human error rates are of the order of 3×10^{-5} per weapon).

For dock fires involving TRU wastes (which bounds LLW), the FSAR Review Team determined a frequency of occurrence of 5×10^{-4}/yr for Building 707 due to the much higher level of activity associated with wastes (SWEC 1991). This frequency was increased to 2×10^{-3}/yr for dock activities associated with Buildings 371, 707, 771, and 776/777. The source term was estimated to be 3.1×10^{-3} g Pu (SWEC 1991), but for this assessment was increased to 1.0×10^{-1} g Pu based on the currently recommended ARF of 5×10^{-4} (all respirable) (Mishima 1994; Kaiser-Hill 1996e) and 200 g Pu maximum limits for TRU waste drums. Consequences (dose and latent cancer fatalities) and risks to the co-located worker, maximally exposed off-site individual, and 50-mile populations from TRU waste dock fires are presented in Table C-5.

For the *Closure* Case, the frequency of dock fires was increased for the SNM metal and oxide, residue, and high-americium residue scenarios by a factor of four due to the increased activity associated with SNM consolidation, and SNM and residue stabilization and repackaging. The frequency of dock fires with potentially pyrophoric plutonium was not changed since it only involves on-site transportation from Building 371 to 707, which was what occurred for the *Baseline* Case during 1996. The frequency for TRU waste fires on docks of plutonium buildings was also not changed for the *Closure* Case. Consequences (dose and latent cancer fatalities) and risks to the co-located worker, maximally exposed off-site individual, and 50-mile populations from these five dock fires are presented in Table C-6. The risk from four of the five dock fire scenarios are eliminated between the years 2002 and 2004, as SNM and residue stabilization and repackaging are completed and SNM is relocated to the new Plutonium Interim Storage Vault. The risk from TRU waste fires on plutonium building docks will not be eliminated until 2010 when DD&D is completed.

C-5.1.6 Fires in TRU Waste Storage Facilities

The Building 664 Final Safety Analysis Report (EG&G 1994z) has evaluated several fire scenarios associated with storage of TRU waste in Butler®-type metal buildings, ranging from a single drum event to a large fire involving multiple drums. A bounding risk scenario is due to spontaneous combustion of Pu-contaminated combustibles in a 55-gallon steel drum. Other fires involving a few to many drums were determined to be less risk because of lower frequency estimates due to failure of the Site's fire protection program and/or automatic sprinkler systems. The frequency of this event was estimated by the Building 664 Final Safety Analysis Report to be 1.7×10^{-3}/yr for 3,000 drums which was increased to 3.3×10^{-3}/yr for 6,000 drums stored during the *baseline* case in buildings without (or no credit for existing) HEPA filtration (i.e., Buildings 334 addition, 569, 664, and 991). For the *closure* case, this frequency is increased to 6.6×10^{-3}/yr assuming that on-site storage will not increase more than a factor of two during DD&D because off-site shipping will start in 1998. Building 440 is scheduled to receive TRU and LLW and has a capacity of up to 8,000 drums (or less because LLW wooden crates will be included). A source term released to the environment of 1×10^{-1} g Pu is calculated the same as discussed above for TRU waste fires on plutonium building docks. Consequences (dose and latent cancer fatalities) and risks to the co-located worker, maximally exposed off-site individual, and 50-mile populations from TRU waste fires in a waste storage facility are presented in Table C-5. For the *Closure* Case, this risk will not be eliminated until 2012 when all material has been shipped off-site.

C-5.1.7 Fires in Low Level Waste Storage Facilities

The Building 664 Final Safety Analysis Report (EG&G 1994z) has evaluated several fire scenarios associated with storage of LLW in Butler®-type metal buildings. Two bounding risk scenarios were identified due to spontaneous combustion of Pu-contaminated combustibles in a plywood box, and an extensive fire involving multiple wooden waste crates. The frequency of

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the single crate fire was estimated to be 4.5x 10^{-2}/yr, and 5.1 x 10^{-3}/yr for the multiple waste crate fire (i.e., by summing two sequences from the event tree analysis for this medium size fire that is successfully contained by the automatic sprinklers or the Fire Department).

The source term released to the environment was recalculated based on the unconfined combustible ARF of 5 x 10^{-2} (Kaiser-Hill 1996e), instead of the confined ARF of 5 x 10-4 for the drum fire discussed above. This is the approach currently being applied for evaluating LLW crate fires and was used for the Building 440 Basis for Operations and environmental assessment (DOE 1996d). Based on the 3 g Pu per LLW crate inventory limit, the source term for one crate is 1.5 x 10^{-1} g Pu. For 15 crate fire, the proposed revisions to the Building 664 Final Safety Analysis Report result in a source term released to the environment of 2.3 x 10^{0} g Pu. Consequences (dose and latent cancer fatalities) and risks to the co-located worker, maximally exposed off-site individual, and 50-mile populations from LLW fires in a waste storage facility are presented in Table C-5. For the *Closure* Case, this risk will not be eliminated until 2012 when all material has been shipped off-site.

C-5.1.8 Fire Risk Summary

Tables C-5 and C-6 summarize the fire scenarios that are presented to portray the risk for the *Baseline* Case and peak year for the *Closure* Case, respectively. For both cases, the risks are essentially the same, until SNM and residues are stabilized and repacked, new storage facilities are built, plutonium buildings are DD&D'd, and SNM and wastes are shipped off-site. The risk to the co-located worker from fires is 1.0 x 10^{-1} rem/yr for the *baseline* case, and is about 10% higher for the *closure* case. The risk to the maximally exposed off-site individual from fires is 1.1x10^{-3} rem/yr for the *baseline* case, and is about 10% higher for the *closure* case. The risk to the 50-mile population from fires is 2.9 x10^{-4} LCF/yr for both cases.

C-5.2 Radiological Explosions

The explosion accident that is considered in most of the Rocky Flats Pu FSARs is an acetylene explosion due to maintenance activities, which bounds those from other potential flammable gases used in Pu buildings (e.g., small propane bottles for laboratory analysis). This explosion scenario assumes that an oxy-acetylene welding rig temporarily located in the Pu processing area is damaged, releasing acetylene that subsequently explodes and severely damages gloveboxes in the room. There are specific procedural controls in place to reduce the risk of an acetylene explosion. The building prohibits compressed gases in storage areas, and quantities necessary for maintenance and constriction are restricted in the process areas. Several events must take place at the same time for a viable scenario. They are: 1) an acetylene cylinder must be present in the processing area; 2) the acetylene cylinder must leak at a rate rapid enough to generate a significant volume of explosive mixture; 3) ventilation must be off or impaired to allow the accumulation of a significant volume of gas; and 4) an ignition source must be present. It is possible that even with no room ventilation, the exit velocity of the gas from the cylinder may be sufficient to disperse it to concentrations below the flammable limit. Based on the FSAR Review Team (SWEC, 1991 and 1992) assessment of this scenario, the probability of occurrence of this accident is 5 x 10^{-5}/yr per Pu building. Of six Pu buildings where sufficient SNM or residues may be present, four could result in a breach of the building and bypass the HEPA filters. A frequency of occurrence for this explosion with bypass is assessed to be 1 x 10^{-4}/yr involving either Buildings 559, 707, 776/777, or 779. For buildings 371 and 771, any release would be filtered by one or two stages of HEPA filters, and its frequency of occurrence would be 1 x 10^{-4}/yr.

The subsequent deflagration is assumed to rupture the gloveports, break the glovebox windows, and cause some bowing of the glovebox structure itself. A release to the environment can occur via the personnel egress doors. The location of the greatest release is

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associated with Building 707 where current thermal stabilization of oxide occurs, and where the new Plutonium Stabilization and Packaging System to meet the requirements of DOE Standard 3013 (DOE 1994x) will be installed. The *SNM consolidation EA* (DOE 1995l) estimated a source term of 3.6 g Pu for a bypass, or 8.6×10^{-4} g Pu from filtered releases.

For the bypass explosion, the consequences would be $5.1 \times 10^{+1}$ rem (CEDE) to the co-located worker, 4.1×10^{-1} rem (CEDE) to the maximally exposed off-site individual, and 5.5×10^{-2} latent cancer fatalities within the 50-mile populations. Risks to these three receptors from bypass explosions would be 1×10^{-2} rem/yr, 8.2×10^{-5} rem/yr, and 1.1×10^{-5} LCF/yr, respectively.

For the filtered explosion, the consequences would be 1.2×10^{-2} rem (CEDE) to the co-located worker, 9.8×10^{-5} rem (CEDE) to the maximally exposed off-site individual, and 1.3×10^{-5} latent cancer fatalities within the 50-mile populations. Risks to these three receptors from filtered explosions would be 1.2×10^{-6} rem/yr, 9.8×10^{-9} rem/yr, and 1.3×10^{-9} LCF/yr, respectively.

The overall risk from explosions is 1×10^{-2} rem/yr to the co-located worker, 8.2×10^{-5} rem/yr to the maximally exposed off-site individual, and 1.1×10^{-5} LCF/yr to the 50-mile population. For the *Closure* Case, this risk from explosions will be reduced as substantial holdup is removed by buildings during the DD&D process (e.g., Building 779 by 2000, Building 771 by 2007, and the remainder by 2010).

C-5.3 Radiological Spills

Numerous spill scenarios have been analyzed by previous NEPA, safety analysis, and emergency preparedness documents. The following spill scenarios were determined to dominate the estimate of risk from radiological spills for the Site, and are further evaluated:

- A spill initiated inside glovebox operations, due either to leaks from gloves or overpressurization.
- A spill initiated inside a plutonium processing area outside of gloveboxes or drums of residues in storage.
- Accidental discharge of a Security Inspector's weapon within a plutonium building.
- A spill during manual transfer of plutonium between buildings.
- A spill on a plutonium building's shipping dock involving plutonium metal or oxide, potentially pyrophoric forms of plutonium, plutonium residues or TRU wastes, high-americium plutonium residues, or pits in DOT Type B shipping packages.
- A spill in a TRU waste or low level waste (LLW) storage building.

C-5.3.1 Releases From Gloveboxes

Releases from gloveboxes have occurred frequently over the Site's operating history, but these were usually associated with small contamination events. Releases from liquid spills are much less than that from oxide. Three bounding spills from gloveboxes were evaluated for the resumption of plutonium operations in Building 707 (SWEC 1991; SWEC 1992) and updated for the *SNM Consolidation EA (DOE 1995l).* These include releases from thermal stabilization of oxide, packaging operations inside gloveboxes, and a flow reversal from the glovebox to the room (i.e., an "overpressurization"). The frequency of these spills were assessed to be 2.5×10^{-1}/yr for thermal stabilization, once per year for packaging operations, 2×10^{-4}/yr for glovebox overpressurizations (DOE 1995l). The *SNM Consolidation EA* determined the source term to be the same for thermal stabilization and repackaging at 1×10^{-6} g Pu, and 9 x

10^{-6} g Pu for glovebox overpressurization (DOE 1995l). Consequences (dose and latent cancer fatalities) and risks to the co-located worker, maximally exposed off-site individual, and 50-mile populations from these spills from gloveboxes are presented in Table C-7. For the *Closure* Case, this risk will be eliminated in the Year 2004 when all SNM stabilization and repackaging is completed, and SNM is stored in the DOE Standard 3013 50-packaging in the new Interim Storage Vault.

Table C-7. Radioactive Spill Risk for *Baseline* Case

			Maximally Exposed Off-site Individual		Co-located Worker		Population	
Spill Scenario	Accident Frequency (per year)	Source Term (g Pu)	Dose rem	Risk rem/yr	Dose rem	Risk rem/yr	Conseq LCF	Risk LCF/yr
Inside GB - therm stab	2.5E-1	1.0E-6	1.1E-7	2.9E-8	1.4E-5	3.5E-6	1.5E-8	3.8E-9
Inside GB - packaging	1.0E+0	1.0E-6	1.1E-7	1.1E-7	1.4E-5	1.4E-5	1.5E-8	1.5E-8
GB pressurization	2.0E-4	9.0E-6	1.0E-6	2.1E-10	1.3E-4	2.5E-8	1.4E-7	2.8E-11
Outside GB 2 HEPA	5.0E-3	1.0E-6	1.1E-7	5.7E-10	1.4E-5	7.0E-8	1.5E-8	7.7E-11
Outside GB 1 HEPA	7.5E-3	5.0E-4	5.7E-5	4.3E-7	7.0E-3	5.3E-5	7.7E-6	5.7E-8
Can corrosion - 2 HEPA	2.0E-2	1.0E-6	1.1E-7	2.3E-9	1.4E-5	2.8E-7	1.5E-8	3.1E-10
Can corrosion - 1 HEPA	3.0E-2	5.0E-4	5.7E-5	1.7E-6	7.0E-3	2.1E-4	7.7E-6	2.3E-7
Firearms - 2 HEPAs	1.8E-2	6.0E-6	6.9E-7	1.2E-8	8.4E-5	1.5E-6	9.2E-8	1.7E-9
Firearms - 1 HEPA	3.6E-2	3.0E-3	3.4E-4	1.2E-5	4.2E-2	1.5E-3	4.6E-5	1.7E-6
Forklift-pit	1.0E-3	5.7E-7	6.5E-8	6.5E-11	8.0E-6	8.0E-9	8.7E-9	8.7E-12
Handling cart	1.0E-4	5.0E-1	5.7E-2	5.7E-6	7.0E+0	7.0E-4	7.7E-3	7.7E-7
Dock - oxide spill	1.0E-3	4.2E-1	4.8E-2	4.8E-5	5.9E+0	5.9E-3	6.4E-3	6.4E-6
Dock - pyrophoric spill	3.0E-4	5.0E-2	5.7E-3	1.7E-6	7.0E-1	2.1E-4	7.7E-4	2.3E-7
Dock - residue drums	1.0E-3	1.5E+0	1.7E-1	1.7E-4	2.1E+1	2.1E-2	2.3E-2	2.3E-5
Dock - hi-Am residues	1.0E-3	5.0E-2	3.6E-2	3.6E-5	4.4E+1	4.4E-3	4.8E-3	4.8E-6
Dock - TRU waste	2.5E-3	4.0E-3	4.6E-4	1.1E-6	5.6E-2	1.4E-4	6.1E-5	1.5E-7
Forklift puncture TRU	5.0E-2	4.0E-3	4.6E-4	2.3E-5	5.6E-2	2.8E-3	6.1E-5	3.1E-6
Spill Risk				3.0E-4		3.7E-2		4.1E-5

C-5.3.2 Releases from Storage Areas

Releases from handling and storage of plutonium in containers outside gloveboxes are much less likely to occur. Four bounding spills in rooms were evaluated, involving dropping containers of oxide or from corrosion of cans storing Pu metal or oxide, and each of these were modeled for releases through one or two stages of HEPA filters depending on the building. The *SNM Consolidation EA (DOE 1995l)* estimated a frequency of spills from dropping cans to be 2.5 x 10^{-3}/yr and 1 x 10^{-2}/yr for container corrosion (DOE 1995l). These frequencies apply per building, so the frequency for a release in Buildings 771, 776/777 and 779 that credit only 1 stage of HEPA filtration would be 7.5 x 10^{-3}/yr and 3 x 10^{-2}/yr, respectively. For Buildings 371 and 707 that still credits two stages of HEPA filtration, the spill frequency would be 5 x 10^{-3}/yr for a dropped can and 2 x 10^{-2}/yr for can corrosion. The *SNM Consolidation EA* determined the source term the same for each type of scenario, i.e., 1 x 10^{-6} g Pu for two stages of HEPA filtration and 5 x 10^{-4} g Pu for one stage of HEPA filtration (DOE 1995l). Consequences (dose and latent cancer fatalities) and risks to the co-located worker, maximally exposed off-site individual, and 50-mile populations from these spills outside gloveboxes are presented in Table C-7.

For the *Closure* Case, the frequency of can corrosion in buildings crediting only one stage of HEPA filters is reduced by one less building (to 2 x 10^{-2}/yr) since all SNM has been removed from Building 779 (but the dropped can scenario will still be applicable during DD&D). Revised estimates of risks to the co-located worker, maximally exposed off-site individual, and 50-mile populations from these spills from can corrosions are presented in Table C-8. The risk from can corrosion will be eliminated by the Year 2004 when all SNM stabilization and repackaging is completed, and SNM is stored in the DOE Standard 3013 50-packaging in the new Interim Storage Vault. The risk from dropping a can will continue though out the DD&D phase, reducing as building holdup is substantially reduced until DD&D is completed in 2010.

Table C-8. Radioactive Spill Risk for *Closure* Case

			Maximally Exposed Off-site Individual		Co-located Worker		Population	
Spill Scenario	Accident Frequency (per year)	Source Term (g Pu)	Dose rem	Risk rem/yr	Dose rem	Risk rem/yr	Conseq LCF	Risk LCF/yr
Inside GB - therm stab	2.5E-1	1.0E-6	1.1E-7	2.9E-8	1.4E-5	3.5E-6	1.5E-8	3.8E-9
Inside GB - packaging	1.0E+0	1.0E-6	1.1E-7	1.1E-7	1.4E-5	1.4E-5	1.5E-8	1.5E-8
GB pressurization	2.0E-4	9.0E-6	1.0E-6	2.1E-10	1.3E-4	2.5E-8	1.4E-7	2.8E-11
Outside GB 2 HEPA	5.0E-3	1.0E-6	1.1E-7	5.7E-10	1.4E-5	7.0E-8	1.5E-8	7.7E-11
Outside GB 1 HEPA	7.5E-3	5.0E-4	5.7E-5	4.3E-7	7.0E-3	5.3E-5	7.7E-6	5.7E-8
Can corrosion - 2 HEPA	2.0E-2	1.0E-6	1.1E-7	2.3E-9	1.4E-5	2.8E-7	1.5E-8	3.1E-10
Can corrosion - 1 HEPA	2.0E-2	5.0E-4	5.7E-5	1.1E-6	7.0E-3	1.4E-4	7.7E-6	1.5E-7
Firearms - 2 HEPAs	1.8E-2	6.0E-6	6.9E-7	1.2E-8	8.4E-5	1.5E-6	9.2E-8	1.7E-9
Firearms - 1 HEPA	2.7E-2	3.0E-3	3.4E-4	9.3E-6	4.2E-2	1.1E-3	4.6E-5	1.2E-6
Forklift-pit	1.0E-3	5.7E-7	6.5E-8	6.5E-11	8.0E-6	8.0E-9	8.7E-9	8.7E-12
Handling cart	1.0E-4	5.0E-1	5.7E-2	5.7E-6	7.0E+0	7.0E-4	7.7E-3	7.7E-7
Dock - oxide spill	4.0E-3	4.2E-1	4.8E-2	1.9E-4	5.9E+0	2.4E-2	6.4E-3	2.6E-5
Dock - pyrophoric spill	3.0E-4	5.0E-2	5.7E-3	1.7E-6	7.0E-1	2.1E-4	7.7E-4	2.3E-7
Dock - residue drums	4.0E-3	1.5E+0	1.7E-1	7.0E-4	2.1E+1	8.6E-2	2.3E-2	9.3E-5
Dock - hi-Am residues	4.0E-3	5.0E-2	3.6E-2	1.4E-4	4.4E+1	1.8E-2	4.8E-3	1.9E-5
Dock - TRU waste	2.5E-3	4.0E-3	4.6E-4	1.1E-6	5.6E-2	1.4E-4	6.1E-5	1.5E-7
Forklift puncture TRU	5.0E-2	4.0E-3	4.6E-4	2.3E-5	5.6E-2	2.8E-3	6.1E-5	3.1E-6
664 crane drop TRU	8.0E-2	6.5E-3	7.4E-4	6.0E-5	9.1E-2	7.3E-3	1.0E-4	8.0E-6
Spill Risk				1.1E-3		1.4E-1		1.5E4-

C-5.3.3 Accidental Weapons Discharge

Potential releases from accidental discharge of a Security Inspector's weapon have also been evaluated for plutonium facilities and were modeled for releases through one or two stages of HEPA filters depending on the building. The *SNM Consolidation EA (DOE 1995l)* estimated a frequency of spills from accidental discharge of a weapon to be 9 x 10^{-3}/yr per building (DOE 1995l). The frequency for a release in Buildings 559, 771, 776/777 and 779 that credit only 1 stage of HEPA filtration would be 3.6 x 10^{-2}/yr. For Buildings 371 and 707 that still credits two stages of HEPA filtration, the weapons-discharge spill frequency would be 1.8 x 10^{-2}/yr. The *SNM Consolidation EA* determined the source term to be 6 x 10^{-6} g Pu for two stages of HEPA filtration and 3 x 10^{-3} g Pu for one stage of HEPA filtration (DOE 1995l). Consequences (dose and latent cancer fatalities) and risks to the co-located worker, maximally exposed off-site individual, and 50-mile populations from these spills from accidental discharge of weapons are presented in Table C-7.

For the *Closure* Case, the frequency of weapons discharge in buildings crediting only one stage of HEPA filters is reduced by one less building (to 2.7 x 10^{-2}/yr) since all SNM has been removed from Building 779. Revised estimates of risks to the co-located worker, maximally exposed off-site individual, and 50-mile populations from these spills from weapons discharge are presented in Table C-8. The risk from weapons discharge will be eliminated by the Year 2004 when all SNM stabilization and repackaging is completed, and SNM is stored in the DOE Standard 3013 50-year containers in the new Interim Storage Vault.

C-5.3.4 Spills During Inter-Building Manual Transfers

The *SNM Consolidation EA* also evaluated potential release while performing manual transfers of Pu metal or oxide on cart between buildings. Buildings 771, 776/777, 779, and 707 are all interconnected and protected by at least one stage of HEPA filtration except for a short distance through Building 778. It estimated a frequency of spills during inter-building transfers at 1 x 10^{-4}/yr, with an unfiltered source term of 5 x 10^{-1} g Pu (DOE 1995l). Consequences (dose and latent cancer fatalities) and risks to the co-located worker, maximally exposed off-site individual, and 50-mile populations from these spills during inter-building transfers are presented in Table C-7. For the *Closure* Case, this risk during inter-building transfers will be eliminated by the Year 2003 when all SNM and residues are removed from Building 776.

C-5.3.5 Dock Spills

Potential spills on the dock of a plutonium facility could involve plutonium metal or oxide, residues (including high-americium), and TRU waste or LLW generated by the facility. Although residue drum spills would bound any releases from TRU waste and LLW drum fires on the dock, TRU wastes are evaluated separately since their risks will exists until the facilities are DD&D'd. The dock spill can be risk-significant because it could result in an unfiltered release to the environment.

The FSAR Review Team (SWEC 1992) estimated the probability of occurrence of a large spill on the dock 1 x 10^{-3}/yr, based on the expected frequency of handling plutonium oxide and probability of breaching a drum (due to human error or mechanical handling). This scenario has been used for the *Environmental Assessment for Resumption of Thermal Stabilization of Plutonium Oxide in Building 707* (DOE 1994p; EG&G 1993j), the *SNM Consolidation EA* (DOE 1995l; EG&G 1995j), and the *Residue Stabilization EA* (DOE 1996c). This frequency was assumed for the following scenarios evaluated, except for a spill (e.g., can overpressurization) from potential pyrophoric forms of plutonium which was estimated to be 3 x 10^{-4}/yr (DOE 1995l).

The *SNM Consolidation EA* (DOE 1995l; EG&G 1995j) estimated the source term from dock spills involving Pu metal and oxide as 4.2 x 10^{-1} g Pu, and spills from potentially pyrophoric forms of Pu as 5 x 10^{-2} g Pu. The *Residue Stabilization EA* (DOE 1996c) estimated the source term from dock spills involving ash residues as 1.5 g Pu, and from high-americium residues as 5 x 10^{-2} g Pu. Consequences (dose and latent cancer fatalities) and risks to the co-located worker, maximally exposed off-site individual, and 50-mile populations from these four dock spills are presented in Table C-7.

For dock spills involving TRU wastes (which bounds LLW), the FSAR Review Team determined a frequency of occurrence of 5 x 10^{-4}/yr for Building 707 due to the much higher level of activity associated with wastes (SWEC 1991). This frequency was increased to 2.5 x 10^{-3}/yr for dock activities associated with Buildings 371, 707, 771, 776/777, and 991. The source term was previously estimated to be 1.3 x10^{-5} g Pu (SWEC 1991), but was increased for this assessment to 4.0 x10^{-3} g Pu based on the currently recommended ARF of 1 x 10^{-3} (10% respirable) (Mishima 1994; Kaiser-Hill 1996e), 200 g Pu maximum limits for TRU

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waste drums, and a 20% damage ratio for the amount of the contents impacted by the forklift. The damage ratio is what was applied for the Building 440 Basis for Operations and is currently proposed for the revision to the Building 664 Final Safety Analysis Report. Consequences (dose and latent cancer fatalities) and risks to the co-located worker, maximally exposed off-site individual, and 50-mile populations from TRU waste dock spills are presented in Table C-7.

For the *Closure* Case, the frequency of dock spills was increased for the SNM metal and oxide, residue, and high-americium residue scenarios by a factor of four due to the increased activity associated with SNM consolidation, and SNM and residue stabilization and repackaging. The frequency of dock spills with potentially pyrophoric plutonium was not changed since it only involves on-site transportation from Building 371 to 707, which was what occurred for the *Baseline* Case during 1996. The frequency for TRU waste spills on docks of plutonium buildings was also not changed for the *Closure* Case. Consequences (dose and latent cancer fatalities) and risks to the co-located worker, maximally exposed off-site individual, and 50-mile populations from these five dock spills are presented in Table C-8. The risk from four of the five dock spill scenarios are eliminated between the years 2002 and 2004, as SNM and residue stabilization and repackaging are completed and SNM is relocated to the new Plutonium Interim Storage Vault. The risk from TRU waste fires on plutonium building docks will not be eliminated until 2010 when DD&D is completed.

C-5.3.6 Spills In Waste Facilities

The Building 664 Final Safety Analysis Report (EG&G 1994z) has evaluated several spills scenarios associated with storage of TRU waste in Butler®-type metal buildings, ranging from a single drum event to a crane dropping a load of 14 drums to be loaded in the TRUPACT vehicle, or 70 drums to be loaded into the ATMX railcar. For the *Baseline* Case, the bounding risk scenario is due to a forklift puncturing two 55-gallon steel drums of TRU waste. Since no forklift punctures of TRU waste drums has ever occurred in Building 664 over its 20 years of operation involving thousands of drum movements, the frequency of this event was estimated to be 5×10^{-2}/yr (i.e., 1 event per 20 years). The source term released to the environment is the same as that recalculated for the TRU waste spill on a plutonium building dock of 4.0×10^{-3} g Pu. Consequences (dose and latent cancer fatalities) and risks to the co-located worker, maximally exposed off-site individual, and 50-mile populations from TRU waste spills in a waste storage facility are presented in Table C-7.

For the *Closure* Case, another scenario is of interest. This involves the loading of TRUPACT II vehicles with a crane which could result in dropping 14 drums or a standard waste box with no more than 325 g Pu total. Loading of the ATMX railcar was not evaluated as current plans are to use the TRUPACT II vehicle. The frequency of this crane accident was estimated to be 8×10^{-2}/yr for TRUPACT II vehicle loading by the Building 664 Final Safety Analysis Report (EG&G 1994z). The source term was recalculated based on current Site methods to be 6.5×10^{-3} g Pu released to the environment based on the 325 g Pu shipping limit per 14 drums being loaded into one TRUPACT II package, currently recommended ARF of 1×10^{-3} (10% respirable) (Mishima 1994; Kaiser-Hill 1996e), and a 20% damage ratio for amount of contents spilled from the 14 drums. The damage ratio is what is currently proposed for the revision to the Building 664 Final Safety Analysis Report. Consequences (dose and latent cancer fatalities) and risks to the co-located worker, maximally exposed off-site individual, and 50-mile populations from crane drops are presented in Table C-8. These risks will not be eliminated until 2012 when all material has been shipped off-site.

C-5.3.7 Risk From Radioactive Spills

Tables C-7 and C-8 summarize the spill scenarios that are presented to portray the risk for the *Baseline* Case and peak year for the *Closure* Case, respectively. For the *Baseline* Case, the risk to the co-located worker from spills is 3.7 x 10^{-2} rem/yr; risk to the maximally exposed off-site individual from spills is 3.0 x 10^{-4} rem/yr; and risk to the 50-mile population from spills is 4.1 x 10^{-5} LCF/yr. For the *Closure* Case, the risk increases by approximately a factor of four due to the increased activities on docks, resulting in risk estimates to the co-located worker from spills of 1.4 x 10^{-1} rem/yr; risk to the maximally exposed off-site individual from spills of 1.1 x 10^{-3} rem/yr; and risk to the 50-mile population from spills of 1.5 x 10^{-4} LCF/yr.

C-5.4 Nuclear Criticalities

A nuclear criticality results from the formation of a critical mass under conditions of proper geometry and moderation, causing the formation of fission products due to the chain reaction that occurs in the special nuclear material. Criticality is possible with plutonium and uranium in solutions, as well as plutonium in metal and oxide forms.

Eleven inadvertent criticality events involving metal systems have occurred in the United States (EG&G 1995j). In Russia, one additional plutonium metal criticality incident occurred (Frolov 1995). All but one of these criticality events occurred in experimental systems. The largest yield from any of these events was in the range from 1 x 10^{17} to 4 x 10^{17} fissions, and involved large masses of plutonium (47 to 96 kilograms) (EG&G 1995j, Frolov 1995). A metal criticality event with a yield of 1 x 10^{18} fissions was included in the 1980 *Final Environmental Impact Statement for the Rocky Flats Plant* (DOE 1980) with an estimated frequency of occurrence of 8 x 10^{-4} per year. In the more recent *Safety Analysis in Support of the Environmental Assessment for Consolidation and Interim Storage of Special Nuclear Materials in Building 371* (EG&G 1995j), the frequency of a metal criticality event was estimated at 1 x 10^{-4} per year on the basis that multiple human errors in violating criticality safety limits would be required to produce a criticality event; the value is in terms of per building per year (EG&G 1995j).

Fifteen solution criticality events have occurred in the United States (EG&G 1995j). In Russia, an additional ten solution criticality events have occurred (Frolov 1995). The maximum yield in any solution criticality event has been 1.2 x 10^{20} fissions (EG&G 1994v). The 1980 *Final Environmental Impact Statement for the Rocky Flats Plant* (DOE 1980) postulated a tank solution criticality in Building 771 resulting in 2.2 x 10^{20} fissions with an estimated frequency of occurrence of 1 x 10^{-7}/yr.

One oxide criticality event has been reported (a uranium oxide powder criticality event in Russia in 1965). The fission product yield from this event was estimated at 1 x 10^{15} fissions (Frolov 1965).

The last criticality event of any kind in Russia or the United States occurred in 1978 (Frolov 1995). Metal criticality frequencies of 5 x 10^{-3} (SWEC 1991), 1 x 10^{-4} (EG&G 1995j), and 1 x 10^{-7} (DOE 1980) per year have been cited in the literature. Solution criticality frequencies of 5 x 10^{-3} per year (SWEC 1991), 1 x 10^{-4} per year (EG&G 1995j), and 1 x 10^{-7} per year (DOE 1980) have been cited in the literature. No frequency estimates for oxide criticality have been identified. The Russian industry experience suggests a criticality frequency of 6 x 10^{-2} per year, but this value depends on the number of facilities operating in a year; a quantitative analysis (using fault trees) of an "average facility" in 1994 provides a more directly useful frequency of 2.4 x 10^{-4} per year (Ryazanov 1995). Based on historical evidence, British Nuclear Fuels estimates the frequency of criticalities by yield. A 1 x 10^{18} excursion yield is estimated to have a frequency of 1 x 10^{-6} per year. The "maximum credible"

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criticality is identified with a yield of 2.0×10^{19} fissions, with a frequency of 1×10^{-7} per year (Austin 1995).

Criticality events can occur as a result of a variety of circumstances, including (Skiles 1995, adapted):

- Events due to human factors (such as improper labeling of fissile material or containers, valving errors, analytical laboratory errors, errors and oversights in written procedures, failure to follow written procedures, improper spacing of fissile materials, or inappropriate application of water in fighting fires)
- Events due to chemical attack on hardware (such as changes in dimension due to corrosion/erosion or due to fire or explosions, leaking valves or process containers, phase changes due to freezing or precipitation that concentrate fissile material, attack or leaching of Raschig rings, or deposits of fissile material in HVAC or other ventilation lines)
- Events due to mechanical failure or design (such as structural failure of passive criticality controls, unintended siphon transfers of fissile solutions or precipitating agents, evaporation or settling of fissile material out of solution, movement of structures or equipment changing reflection and/or approved spacing, blockage of overflows and drains, piping or container failure resulting in leaks of fissile solutions into unapproved locations, or vacuums or pressure transients moving fissile materials into unapproved locations)
- Events due to temperature (such as phase changes that concentrate fissile materials, phase changes that rupture process vessels, or thermal expansion changing safe dimensions)
- Events due to natural phenomena or man-made hazards (such as damage to structures or containment from high wind or tornadoes; interruption of Site utilities due to high winds or lightning; malfunction of electronic controls due to lightning-induced surges or wind-driven rain; introduction of moderation into unapproved areas by high wind or earthquake; loss of required spacing due to high winds or earthquakes; or disruption of safe geometry due to earthquakes, high wind, or aircraft crash)

Clearly, with such a variety of potential criticality initiators, a very detailed analysis would be required to comprehensively assess the risk associated with criticality events involving uranium and plutonium in the variety of circumstances present at the Site (including uranium and plutonium nitrate solutions and metals and oxides in various forms and sizes). The frequency of 1×10^{-4} per year per building from the *Safety Analysis in Support of the Environmental Assessment for Consolidation and Interim Storage of Special Nuclear Materials in Building 371* (EG&G 1995j) was used for all criticality events (single spike and 8 hour plutonium solutions, plutonium metal, and plutonium oxide) in the *Baseline* Case, except for uranium solution criticalities which was 1.2×10^{-3}/yr (EG&G 1995m). The 8-hour solution criticality will be eliminated when solution stabilization is completed by the year 1998 because these solutions will be converted into an oxide. For the *Baseline* Case, plutonium solutions are present in two buildings (Buildings 371 and 771) with a frequency of 2×10^{-4}/yr, either for the single-spike or 8-hour solution criticality. Plutonium metal and oxide are present in five buildings in the *Baseline* Case for a frequency of 5×10^{-4}/yr.

A nuclear criticality may be characterized by a flash of fissions that produce a pulse of penetrating radiation, followed by a period of much lower radiation lasting from a few minutes to several hours depending on the self-limiting properties of the critical mass. A criticality is

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very different from a nuclear detonation, which is instantaneous fissioning of all material. There is no potential for a nuclear detonation at the Site.

The criticality source terms are very different from the source terms for non-criticality accidents presented for fires, explosions, and spills. Criticalities are categorized as either metal or solution criticalities. When developing criticality source terms, there are several variables which significantly effect the source terms. These are 1) total number of fissions; 2) fission rate as a function of time; 3) duration of the criticality; 4) neutron energy spectrum in the fissile system; and 5) concentration of actinides (EG&G 1994w).

The plutonium metal in air criticality fission yield was 1×10^{18} fissions for the 1980 FEIS. For this CID assessment, a water-moderated/reflected plutonium oxide criticality has a greater consequence than a metal in air or water-moderated/reflected metal criticality. The fission yield for a damp oxide criticality is recommended by the Site contractor to be modeled as 1×10^{19} fissions which is higher than those recommended in the DOE release fraction handbook (Mishima 1994). A plutonium solution criticality fission yield of 1×10^{18} fissions for a single-spike and 1×10^{19} fissions for an 8-hour multiple spike criticality are assumed as recommended in the DOE release fraction handbook (Mishima 1994). The uranium solution criticality fission yield was 6.2×10^{20} fissions per the contractor's safety evaluation (EG&G 1994m).

Criticality events result in a chain reaction and fissioning of special nuclear material (either plutonium or highly enriched uranium). Fissioning results in the production of fission products (e.g., radioactive noble gases such as krypton and xenon, as well as other fission products such as iodine, cesium, and strontium), which can be released from the criticality site. The criticality source terms are based on calculations using the ORIGEN code or are based on U.S. Nuclear Regulatory Commission Regulatory Guide 3.34 (in the case of the uranium criticality). The code results were used directly, with the exception that the Regulatory Guide 3.34 values were multiplied by 62 to account for a greater number of fissions (1×10^{19} in the Regulatory Guide versus 6.2×10^{20} assumed for the Building 886 Basis for Interim Operations). The values for the plutonium metal and plutonium water-moderated source terms are from the Site's radiological dose template that is also used for plutonium particulate releases discussed earlier (Kaiser-Hill 1996e).

Consequences (dose and latent cancer fatalities) and risks to the co-located worker, maximally exposed off-site individual, and 50-mile populations from criticalities are presented in Table C-9 and C-10 for the *Baseline* Case and *Closure* Case, respectively.

Table C-9. Criticality Risk for *Baseline* Case

Criticality Scenario	Accident Frequency (per year)	Source Term (fissions)	Maximally Exposed Off-site Individual Dose rem	Maximally Exposed Off-site Individual Risk rem/yr	Co-located Worker Dose rem	Co-located Worker Risk rem/yr	Population Conseq LCF	Population Risk LCF/yr
Water-moderated Pu oxide or metal	5.0E-4	1.0E+19	1.4E-3	7.0E-7	1.5E-1	7.5E-5	6.0E-4	3.0E-7
Single-spike Pu solution	2.0E-4	1.0E+18	2.7E-3	5.4E-7	3.9E-1	3.9E-5	6.0E-5	6.0E-9
8-hr Plutonium solution	2.0E-4	1.0E+19	1.2E-2	2.4E-6	1.7E+0	3.4E-4	6.0E-4	1.2E-7
8-hr Uranium solution	1.2E-3	6.2E+20	1.9E+0	2.3E-3	3.5E+2	4.2E-1	3.7E-2	4.5E-5
Criticality Risk				2.3E-3		4.2E-1		4.5E-5

For the *Baseline* Case, the risk to the co-located worker from criticalities is 4.2×10^{-1} rem/yr; risk to the maximally exposed off-site individual from criticalities is 2.3×10^{-3} rem/yr; and risk to the 50-mile population from criticalities is 4.5×10^{-5} LCF/yr. For the *Closure* Case,

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the risk decreases by approximately three orders of magnitude due to off-site shipping of the HEUN solutions from Building 886. For the *Closure* Case, this results in risk estimates to the co-located worker from spills of 4.9 x 10^{-4} rem/yr; risk to the maximally exposed off-site individual from spills of 3.6 x 10^{-6} rem/yr; and risk to the 50-mile population from spills of 4.3 x 10^{-7} LCF/yr. The 8-hr solution criticality should be eliminated when the residue solution stabilization program is completed, but the single-spike solution Pu solution criticality is not eliminated until the end DD&D in the year 2010. Likewise, the damp oxide criticality is not eliminated until the end of DD&D, although there will be some reduction from elimination of metals and bulk oxides when material is repackaged in the DOE Standard 3013 containers, and residue stabilization activities are completed in the 2002 to 2004 timeframe.

Table C-10. Criticality Risk for *Closure* Case

Criticality Scenario	Accident Frequency (per year)	Source Term (#fissions)	Maximally Exposed Off-site Individual		Co-located Worker		Population	
			Dose (rem)	Risk rem/yr	Dose (rem)	Risk (rem/yr)	Conseq (LCF)	Risk (LCF/yr)
Water-moderated Pu oxide or metal	5.0E-4	1.0E+19	1.4E-3	7.0E-7	1.5E-1	7.5E-5	6.0E-4	3.0E-7
Single-spike Pu solution	2.0E-4	1.0E+18	2.7E-3	5.4E-7	3.9E-1	3.9E-5	6.0E-5	6.0E-9
8-hr Plutonium solution	2.0E-4	1.0E+19	1.2E-2	2.4E-6	1.7E+0	3.4E-4	6.0E-4	1.2E-7
Criticality Risk				3.6E-6		4.9E-4		4.3E-7

C-5.5 Earthquakes

The Site's plutonium buildings are of varied construction. Building 371 is a modern building designed to seismic standards (including a design basis earthquake defined in the 1970's) and is constructed of reinforced concrete. Buildings 559 and 779 are constructed of concrete block. Buildings 776 and 777 are built of concrete block and steel and asbestos-cement panels. Building 707 is constructed of precast concrete panels. It is understandable, therefore, that variations in seismic resistance are to be expected.

Earthquakes were not modeled in the 1980 *Final Environmental Impact Statement for the Rocky Flats Plant* (DOE 1980). Rather, that document made a commitment that investigations were under way into the resistance of the Site buildings to seismic events, and that these investigations would be published in plutonium building safety analysis reports. Additional seismological data were also being researched.

These structural studies indicated that the Site's plutonium buildings are vulnerable to earthquake-induced damage, including structural collapse. A risk assessment based on these structural evaluations was conducted for the *Long Range Rocky Flats Utilization Study* (DOE 1982) and provided to the public in response to the Lamm-Wirth Task Force recommendations from the 1970's. The Long Range Utilization Study concluded that seismic and extreme events dominate estimates of risk to the public. A structural upgrade project was initiated that completed seismic and wind upgrades to several of the plutonium facilities (e.g., Buildings 559, 707 Modules J and K only, and 779).

Additional seismic evaluations were performed for the plutonium buildings FSARs (FSARs 1980s). Results (Rockwell 1986) confirmed the previous conclusion that seismic and wind risks dominate risk to the public compared to other operational accidents and aircraft crashes.

The *SNM Consolidation EA* assessment also concluded that seismic events dominate risk to the public for storage of SNM in Building 371 when compared to other operational accidents, natural phenomena events, and aircraft crashes. Seismic risks were due to substantial contributions from two different earthquakes: (1) the RFETS design basis earthquake (DBE) of 0.21g surface acceleration in effect at the time of the evaluation (which is about the same or slightly greater than Building 371 DBE of 0.14g at 40-foot sub-basement level); and (2) from a more severe earthquake beyond the design basis (i.e., 0.3g surface acceleration) that could fail safety systems and cause a significant release of plutonium to the environment, but would not structurally collapse the building..

Recent studies also indicated that the frequency of earthquakes in excess of the Site's previously-defined design basis earthquake was larger than previously believed. A state-of-the-art seismic hazard study was completed for the Site in September 1994. This study produced estimates of Peak Ground Acceleration at bedrock (EG&G 1994o). Peak Ground Acceleration is the largest ground acceleration produced by an earthquake at a site. It usually refers to the horizontal ground motion (i.e., the average of the two largest horizontal acceleration components of the earthquake ground motion at a site) (DOE 1996k). The new seismic hazard curve must be applied with building-specific response and soil amplification characteristics. To date, this has only been performed for Building 371 and not any of the older plutonium buildings. From that assessment, a Performance Category 3 earthquake defined by a 2,000-year return period (5×10^{-4}/yr) for Building 371 would have an acceleration of 0.25g at the ground surface level.

In an earthquake, if a building does not fail structurally, the high-efficiency particulate air filtration system could be available and the resulting releases will be substantially reduced. However, the earlier studies of vital safety systems concluded that electrical power and HVAC ductwork could fail during more likely earthquakes (EG&G 1994w). Several levels of earthquake damage ranging from a "threshold damage" to "total damage" (or the Site's design basis earthquake, whichever was smaller) were evaluated for the plutonium buildings final safety analysis reports (FSARs 1980s). Although these more frequent earthquakes that did not result in "total damage" were significant contributors to overall Site risks, the FSAR assessments did not include complete collapse of all facilities. Therefore for the purpose of this CID assessment to compare the *Closure* Case to the *Baseline* Case, building collapse—which results in a much larger source term and was shown by a recent updated assessment for resumption of plutonium operations in Building 707 to be the dominant contributor to risks (SWEC 1991 and 1992) —is evaluated and these small earthquake scenarios that do not result in building collapse were screened from further analysis.

Based on the previous FSAR assessments and the insights gained from the new Seismic Hazard Curve and evaluations of Building 371 for DNFSB Recommendation 94-3, the seismic frequencies for collapse are assumed as shown in Table C-11. The Building 707 estimates are from the FS*AR* rebaseline assessments for resumption of plutonium operations (SWEC 1991 and 1992). Most of the other estimates are slightly more conservative than their FSAR seismic evaluations due to the change in seismic evaluation methodologies (DOE 1996k) and the increased probabilities associated with the new Seismic Hazard Curve (EG&G 1994o).

The Building 371 estimate is from the "pushover" analysis performed for DNFSB Recommendation 94-3 Implementation Plan Task 6 analysis (DOE 1995ii) that concluded a best estimate of 35,000 year return period. For the new Interim Storage Vault that will be built to a Performance Category 4 10,000-year earthquake, which is an event that should be greater than the largest earthquake that the region's geology should support. Therefore, no releases are expected from the facility that will be designed with safety class structures, systems, and components to protect the public. Although the Building 371 was determined to withstand a 10,000-year earthquake, it's collapse is included in this CID assessment due to the uncertainties associated with the current probabilistic methods (DOE 1996k) to establish

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appropriate seismic design basis criteria (i.e., Building 371 was designed for a Richter magnitude 6.0 Design Basis Earthquake in the early 1970's that was believed at that time to be the largest magnitude earthquake that the region's geology could support.)

Table C-11. Seismic Collapse Frequency Estimates

Seismic-Induced Building Collapse	Return Period (years)	Frequency of Occurrence (per year)
Building 559 and TRU waste steel storage buildings	500	2×10^{-3}
Building 707 Modules A through H	550	1.8×10^{-3}
Building 374	900	1.1×10^{-3}
Buildings 771, 776/777, and 991 (excluding underground vaults)	1,000	1×10^{-3}
Buildings 779 and 707 Modules J & K	1,250	8×10^{-4}
Building 371	35,000	2.9×10^{-5}

Most building source terms were developed by updating the *Defense Nuclear Facilities Safety Board Recommendation 94-3, Rocky Flats Environmental Technology Site, Implementation Plan: Task 9, Provide Recommendations and Bases for Interim SNM Management, Deliverable 9-1: Risk Assessment of Building 371 Baseline and Alternatives for Consolidation of SNM.* (DOE 1995jj). This document analyzed numerous alternatives for reducing the risks from storage of SNM and residues. The general methodology and assumptions of the Task 9 analysis were applied for this CID assessment, although some assumptions have been revised for the cases presented in this analysis.

For the *Baseline* Case, the building collapse source terms are calculated based on the methodology described in Section C-4, and the current classified inventory distribution of plutonium metal and oxide by building (rather than the unclassified estimates provided in Chapter 2 of this CID because the source term is dominated by releases from oxides rather than metals). The residue and TRU waste inventories, as well as Pu holdup in facilities, as shown in Chapter 2 of this CID were also included in the source term evaluation. The total grams of plutonium includes the dose-equivalence from the estimated 40 kg of americium in residues. Table C-12 summarizes the source terms from the buildings evaluated, as well as radiological consequences and risks for the *Baseline* Case.

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Table C-12. Seismic Risk for *Baseline* Case

Seismic Scenario	Accident Frequency (per year)	Source Term (g Pu)	Maximally Exposed Off-site Individual Dose rem	Risk rem/yr	Co-located Worker Dose rem	Risk rem/yr	Population Conseq LCF	Risk LCF/yr
Building 371	2.9E-5	5.6E+2	6.4E+1	1.8E-3	7.9E+3	2.3E-1	8.6E+0	2.5E-4
Building 374	1.1E-3	3.0E-2	3.4E-3	3.8E-6	4.2E-1	4.7E-4	4.6E-4	5.1E-7
Building 559	2.0E-3	1.4E-1	1.6E-2	3.2E-5	2.0E+0	3.9E-3	2.1E-3	4.3E-6
TRU building (374, 569, 664)	2.0E-3	1.3E-1	1.5E-2	3.0E-5	1.8E+0	3.7E-3	2.0E-3	4.0E-6
Building 707A-H	1.8E-3	5E+0	5.7E-1	1.0E-3	7.0E+1	1.3E-1	7.7E-2	1.4E-4
Building 707J-K	8.0E-4	2.9E+1	3.3E+0	2.6E-3	4.0E+2	3.2E-1	4.4E-1	3.5E-4
Building 707 total[1]		3.4E+1	3.9E+0	3.7E-3	4.7E+2	4.5E-1	5.2E-1	4.9E-4
Building 771/774	1.0E-3	1.7E+2	1.9E+1	1.9E-2	2.4E+3	2.4E+0	2.6E+0	2.6E-3
Building 776/777	1.0E-3	1.3E+2	1.5E+1	1.5E-2	1.8E+3	1.8E+0	2.0E+0	2.0E-3
Building 779	8.0E-4	2.8E+0	3.2E-1	2.6E-4	3.9E+1	3.2E-2	4.3E-2	3.4E-5
Building 991 (excluding vaults)	1.0E-3	1.0E-1	1.1E-2	1.1E-5	1.4E+0	1.4E-3	1.5E-3	1.5E-6
Seismic Risks		9.0E+2	1.0E+2	4.0E-2	1.3E+4	4.9E+0	1.4E+1	5.4E-3

[1]The building 707 total is not double-counted in the Seismic Risk totals.

The source terms, consequences , and risks for the peak year of the *Closure* Case is shown in Table C-13. Risk increases in the near term to start up residue stabilization and repackaging operations in Building 707 (Modules A through H). The *Residue Stabilization EA* (DOE 1996c) evaluated releases from seismic collapse of Building 707 and concluded a small additional source term. However, more material-at-risk is anticipated to be staged throughout the facility than originally evaluated, and current safety analyses are being performed to identify a bounding estimate of MAR and appropriate controls to reduce the MAR to ALARA levels. Since that evaluation is not yet completed, this CID assessment assumed that the MAR limit would be established at a level that would not exceed the radiological citing criterion of 25 rem CEDE at the Site boundary (DOE 1989) from any combined plutonium and americium releases from residue stabilization activities that would occur from collapse of Modules A through H. Since a citing analysis requires more conservative assumptions to identify safety class structures, systems, and components to protect the public (e.g., 95th percentile dispersion conditions), a back-calculated estimate of approximately 22.5 g Pu released was added to the Building 707 Module A through H *Baseline* source term. As SNM and residue stabilization and repackaging are completed, seismic risks will be dominated by Pu holdup in the facilities until most of the dispersible holdup is remediated by DD&D activities. Then seismic risk is due to storage in TRU waste steel buildings and the Interim Storage Vault until the material is shipped off-site.

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Table C-13. Seismic Risk for *Closure* Case

Seismic Scenario	Accident Frequency (per year)	Source Term (g Pu)	Maximally Exposed Off-site Individual		Co-located Worker		Population	
			Dose rem	Risk rem/yr	Dose rem	Risk rem/yr	Conseq LCF	Risk LCF/yr
Building 371	2.9E-5	5.6E+2	6.4E+1	1.8E-3	7.9E+3	2.3E-1	8.6E+0	2.5E-4
Building 374	1.1E-3	3.0E-2	3.4E-3	3.8E-6	4.2E-1	4.7E-4	4.6E-4	5.1E-7
Building 559	2.0E-3	1.4E-1	1.6E-2	3.2E-5	2.0E+0	3.9E-3	2.1E-3	4.3E-6
TRU building (440, 569, 664)	2.0E-3	1.3E-1	1.5E-2	3.0E-5	1.8E+0	3.7E-3	2.0E-3	4.0E-6
Building 707A-H	1.8E-3	2.7E+1	3.1E+0	5.7E-3	3.9E+2	7.0E-1	4.2E-1	7.6E-4
Building 707J-K	8.0E-4	2.9E+1	3.3E+0	2.6E-3	4.0E+2	3.2E-1	4.4E-1	3.5E-4
Building 707 total[1]		5.6E+1	6.4E+0	8.3E-3	7.9E+2	1.0E+0	8.6E-1	1.1E-3
Building 771/774	1.0E-3	1.7E+2	1.9E+1	1.9E-2	2.4E+3	2.4E+0	2.6E+0	2.6E-3
Building 776/777	1.0E-3	1.3E+2	1.5E+1	1.5E-2	1.8E+3	1.8E+0	2.0E+0	2.0E-3
Building 779	8.0E-4	2.8E+0	3.2E-1	2.6E-4	3.9E+1	3.2E-2	4.3E-2	3.4E-5
Building 991 (excluding vaults)	1.0E-3	1.0E-1	1.1E-2	1.1E-5	1.4E+0	1.4E-3	1.5E-3	1.5E-6
Seismic Risks		9.2E+2	1.1E+2	4.5E-2	1.3E+4	5.5E+0	1.4E+1	6.0E-3

[1]The building 707 total is not double-counted in the Seismic Risk totals.

C-5.6 High Wind

Since the Site's plutonium buildings were upgraded in their wind resistance, only Building 776/777 is vulnerable to credible high wind events. Natural phenomena hazard upgrades to Buildings 559, 707, and 779 have rendered them much less susceptible to high wind damage. The *Safety Analysis in Support of the Environmental Assessment for Consolidation and Interim Storage of Special Nuclear Materials in Building 371* (EG&G 1995j) indicates that only Building 776/777 is vulnerable to damage as a result of the design basis wind. In fact, at wind speed of 110 mph, Building 776/777 is projected to experience "threshold damage" resulting in breach of exterior walls, and at 150 mph, it is expected to sustain "total damage" (not resulting in collapse of the roof and second floor, but extensive damage that renders the structure uninhabitable, requiring demolition and reconstruction") (EG&G 1995j). Building 776/777 experiences severe damage in a high wind scenario, including failure of some interior and exterior walls. Material is stored in this building in unsealed containers on heat detectors in gloveboxes, as well as in containers stored in vaults. Additional releases arise from damage to ventilation exhaust piping containing plutonium contamination. The source term is estimated at 20 grams of respirable plutonium (EG&G 1995j). Based on the lower dispersion factor for high winds discussed earlier, consequences (dose and latent cancer fatalities) and risks to the co-located worker, maximally exposed off-site individual, and 50-mile populations from high winds would be $2.8 \times 10^{+1}$ rem (CEDE) to the co-located worker, 2.3×10^{-1} rem (CEDE) to the maximally exposed off-site individual, and 3.1×10^{-1} latent cancer fatalities. Based on a design basis wind frequency of 1×10^{-4}/yr and these consequences, the risk to the co-located worker from spills is 2.8×10^{-3} rem/yr; risk to the maximally exposed off-site individual from spills is 2.3×10^{-5} rem/yr; and risk to the 50-mile population from spills is 3.1×10^{-5} LCF/yr.

Buildings 707 and 776/777 were evaluated in the *Safety Analysis in Support of the Environmental Assessment for Consolidation and Interim Storage of Special Nuclear Materials in Building 371* (EG&G 1995j) as being vulnerable to tornado missiles. However, the estimated releases were identified as very small (5×10^{-5} grams for Building 707 to 3×10^{-3} grams for Building 776/777). Given the assessed frequency of 1×10^{-6} per year for design-basis tornado-generated missiles (and allowing no reduction for chance of hitting a vulnerable

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area with plutonium), such small releases will not impact the risk estimates for the Site , and tornado missiles were screened from further consideration.

C-5.7 Aircraft Crash

Aircraft crash into plutonium buildings at the Site is a relatively low frequency but potentially high-consequence accident scenario, because the crash and resulting fuel fire is essentially a "common mode failure." That is, a single event provides breach of confinement, breach of plutonium storage packages, breach of the high-efficiency particulate air filtration system, and a fire to disperse the plutonium into the environment.

The 1980 *Final Environmental Impact Statement for the Rocky Flats Plant* (DOE 1980) applied the event tree analysis technique to evaluate 309 scenarios involving crashes of small and large aircraft from two airports (Jefferson County and Stapleton International) crashing into the plutonium areas of the Site and releasing up to 1,000 g Pu. From this evaluation, the Final Environmental Impact Statement (FEIS) provided risk perspectives from two scenarios: a "typical aircraft accident" resulting in the release of 6 grams (0.44 Ci) at a frequency of 6×10^{-5} per year, and the other a "maximum credible aircraft accident" resulting in the release of 100 grams (7.3 Ci) at a frequency of 1.3×10^{-7} per year. The risk in terms of expected release per year from these two scenarios is 3.7×10^{-4} grams/yr, which was also the weighted sum of all 309 scenario probabilities times source terms. The 100 g Pu source term has been used by the Site and the State as the Site's maximum credible accident for off-site emergency planning purposes since this evaluation was initially prepared in the mid-1970's.

The aircraft crash accident analysis for this CID assessment is based on a more recent evaluation of aircraft crashes contained in the *Analysis of Off-site Emergency Planning Zones for the Rocky Flats Plant* (EG&G 1992i). This assessment has been applied to most recent environmental assessment and safety analysis authorization basis projects affecting plutonium facilities. That assessment applied the FEIS event tree analysis methodology and applied updated data on aircraft crash frequencies, material-at-risk estimates representative of plutonium processing activities, newer release fractions, and current radiological consequence methodologies. It determined source terms on the same order of magnitude as the FEIS, and validated that the maximum consequences of a credible accident were less than 100 g plutonium respirable release from a small or large aircraft[15]. This assessment produced a histogram similar to the FEIS analysis which was integrated for this CID assessment to determine that the weighted risk in terms of expected release per year of all scenarios evaluated is 2×10^{-5} grams/yr, approximately a factor of 20 less than the results of the FEIS assessment. For this CID assessment, the weighted risk-release value is converted to radiological risk estimates for the three receptors of interest by using the lofted fire unit dose conversion and latent cancer fatality conversion factors. This results in a risk to the co-located worker from aircraft crashes of 2.2×10^{-7} rem/yr; risk to the maximally exposed individual off-site individual from spills is 6.4×10^{-7} rem/yr; and risk to the 50-mile population from spills is 3.7×10^{-7} LCF/yr. Individual probabilities and radiological consequences are not presented for this CID assessment.

For the *Closure* Case, SNM consolidation and residue stabilization and repackaging will reduce the risk from aircrafts as material is stored consolidated into the new Plutonium Interim Storage Vault or residues are repackaged into the pipe component and stored in TRU waste facilities. To represent the risk from the remaining plutonium holdup or TRU waste facilities, the risk is assumed to be bounded by the original maximum credible accident of a 100 g Pu

[15] Note: Both the 1980 Rocky Flats FEIS and the Fourth MCA review evaluated lower probability crashes and estimated greater than 100 g plutonium releases, but these are not considered as credible aircraft crashes warranting further evaluation for offsite emergency planning. Also these lower probability higher consequence aircraft crashes are not risk dominant because of the higher probability small plane crashes.

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release with a probability of occurrence of 1 x1 0^{-7}/yr, which is approximately one-third the risk for current *Baseline* conditions and the peak *Closure* Case.

C-5.8 Radiological Accident Summary

Risks from radiological accidents are summarized and interpreted in the Executive Summary and Section 5.14, "Impacts Resulting from Potential Accidents," of this CID. Essentially, seismic events dominate risks until well through DD&D when plutonium holdup is eliminated, and then other contributors such as radioactive waste fires become important.

C-6 Chemical Accidents

The primary mission of the Site has been to shape components from plutonium and other metals for the Department of Energy. Plant operations once involved fabrication and recovery of plutonium; waste treatment, storage, and shipment for off-site disposal; operating several chemical laboratories; and performing research and development. Because of the wide variety of operations that have been conducted at the Site, the amounts and concentrations of the chemicals used varied widely. In most cases, the quantities were small and in dilute form; however, in some operations, the chemicals were used in large quantities and/or in high concentrations. Now due to limited Site operations, the inventory of chemicals has been substantially reduced from earlier levels. Nonetheless, substantial amounts of ammonia, chlorine, sulfur dioxide, nitric acid, sulfuric acid, and propane are maintained at the Site. A risk of releasing these chemicals into the environment is possible due to equipment failure, operator error, transportation activities, or natural disasters, such as earthquakes. These situations, if they were to occur, would be considered accident scenarios.

This section describes the process used to identify the chemicals (toxic and flammable substances) for accident analysis, the methodology used in analyzing potential accidents involving hazardous chemicals, the baseline accident scenarios, and the potential health risks associated with a release from the identified scenarios. The Site chemical accident scenarios addressed here are:

TOXIC SUBSTANCE RELEASES:

- A release of one-150 pound cylinder of ammonia from Building 881;
- A release of two-150 pound cylinders of chlorine from Building 995, part of the Site Waste Water Treatment Plant (WWTP);
- A release of two-150 pound cylinders of sulfur dioxide from Building 995;
- A release of 90,000 pounds of a nitric acid mixture (56% nitric acid by weight) from the outside storage tank (D222) at the Building 371/374 Complex; and

FLAMMABLE SUBSTANCE RELEASE:

- A propane release and subsequent unconfined vapor cloud explosion (UVCE) at the P705 or the P904 propane tank farms. Each tank farm contains eight-1,000 gallons tanks interconnected to a common manifold.

Postulated releases of the additional chemicals stored on-site may occur; however, they are considered to have lesser impact than the release scenarios postulated here.

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C-6.1 Chemical Accident Analysis Methodology

Accidents involving ammonia, chlorine, sulfur dioxide, and nitric acid were considered to be inadvertent releases of toxic materials from confinement to the environment resulting in physical injury or property damage. The accident involving propane was considered to be a release of a flammable substance and subsequent UVCE that could cause injury to personnel or damage to nearby structures due to explosion overpressure effects. Postulated accidents included events which could result from external initiators (e.g., vehicle crashes, explosions, etc.), internal initiators (e.g., equipment failures, human error, etc.), and natural phenomena initiators (e.g., earthquakes, tornadoes, etc.).

TOXIC SUBSTANCE RELEASES:

The accident screening approach for this analysis utilized the internal, external, and natural phenomena initiators for accident screening, which were developed for accident analysis for this CID as described in Section C-3.2. Many accident scenarios can be postulated for the Site; however, to analyze all potential accident scenarios and their associated impacts would not be realistically possible. Therefore, five accident scenarios were developed and analyzed, four toxic substance releases and one flammable substance release.

For the ammonia, chlorine, and sulfur dioxide release scenarios from 150 pound cylinders, the initiating event was assumed to be a cylinder valve failure or manifold failure (caused by mechanical failure or physical damage) that releases the contents.

For the nitric acid release, a catastrophic failure (such as might be caused by a beyond-design-basis earthquake) of the 16,000 gallon nitric acid storage tank outside the Building 371/374 Complex was postulated.

The consequences of releases of ammonia, chlorine, sulfur dioxide, and nitric acid were estimated utilizing maximum potential airborne concentrations at receptor locations at various distances from the release location (point of release). The airborne concentrations at the receptor locations were estimated using airborne dispersion modeling in the CAMEO/ALOHA code (see Section C-6.1.2). The concentrations are expressed in terms of the Emergency Response Planning Guidelines (ERPGs) (See Section C-6.1.2).

Information involving the use of toxic substances was reviewed to identify those chemicals with a potential for onsite/offsite releases to Site workers and the general public. In general, the methodology used to screen the chemicals included: 1) identifying toxic chemicals present in quantities exceeding the threshold planning quantities (TPQs) listed in 40 CFR Part 355 (SARA Title III requires emergency planning and reporting for the extremely hazardous substances present in excess of the threshold planning quantities) or the threshold quantities (TQs) listed in 40 CFR Part 68, *Accidental Release Prevention Requirements: Risk Management Programs*; 2) modeling a credible release of the identified toxic chemicals to the atmosphere to determine airborne concentrations at the receptor locations; and 3) comparing those airborne concentrations to the ERPG values. Upon determining the chemicals that represent realistic accident consequences, exposure assessments for the identified receptors were conducted and dose assessments based on the postulated exposures were developed.

FLAMMABLE SUBSTANCE RELEASE:

For the propane release scenario and subsequent UVCE, the initiating event was assumed to be a catastrophic failure of one of the eight-1,000 gallon storage tanks at either tank farm location (P750 and P904). The P750 propane tank farm is located inside the Protected Area (PA) and the P904 tank farm is located outside the PA south of Central Avenue and the 904 pad area.

The consequence of a release of propane and subsequent UVCE were estimated assuming that the maximum released quantity forms a vapor cloud that detonates. The maximum overpressure due to the explosion was estimated using the Unconfined Vapor Cloud Explosion Model in the ARCHIE code (see Section C-6.1.2). The consequences were estimated by determining the distance to various overpressure levels (expressed in psig).

Information involving the use of flammable substances was reviewed to identify those chemicals with a potential for onsite/offsite impact to Site workers and the general public. In general, the methodology used to screen the chemicals included: 1) identifying flammable chemicals present in quantities exceeding the threshold quantities (TQs) listed in 40 CFR Part 68 or 29 CFR 1910.119, *Process Safety Management of Highly Hazardous Chemicals*, and 2) modeling a credible release and subsequent unconfined vapor cloud explosion (UVCE) as a worst-case scenario. Upon determining the chemical(s) that represent realistic accident consequences, an exposure assessment for the identified receptors was conducted and injury/damage assessments based on the postulated exposures were developed.

C-6.1.1 Analysis Screening Thresholds

This review was based on the chemicals and quantities listed in the 1996 SARA Title III report (EG&G 1995k), information on volatility, Emergency Response Planning Guidelines (ERPG-1, -2, and -3) concentrations for the chemicals listed in the SARA Title III report, and a review of the Integrated Chemical Management System (ICMS) database to screen for hazardous substances (toxic and flammable) that exceed TPQs or TQs (Table C-14 contains the results of the screening process). The screening process indicated that a detailed review should be performed for ammonia, chlorine, sulfur dioxide, nitric acid, and propane. Detailed chemical analysis and dispersion modeling were conducted for quantities of the above mentioned chemicals involved in the postulated accident scenarios not necessarily the total amounts (at a single location/building) indicated in the SARA Title III report and Table C-14.

C-6.1.2 Model Selection Criteria

TOXIC SUBSTANCE RELEASES:

The analytical methods used to model the airborne release of toxic chemicals focus on the selection of a suitable model that best characterize chemical plumes, determine conservative chemical dispersion parameters, and establish an estimate of exposure concentrations at which adverse effects can be expected based on exposure to a specific chemical. The following section describes the basis for selecting the computer code for this analysis.

The computer code chosen for computation of dose was Computer Aided Management of Emergency Operations (CAMEO)/Areal Locations of Hazardous Atmospheres (ALOHA) Version 5.2 developed by the National Safety Council, the EPA, and the National Oceanic and Atmospheric Administration. This code is distributed by the National Safety Council's Environmental Health Center for the purpose of saving lives and protecting public health during emergency events. ALOHA allows for the modeling of airborne releases of chemicals via either a dense gas or gaussian calculation. ALOHA defines the plume at pre-determined threshold concentrations (levels of concern) as well as predicting chemical concentrations within the plume at desired distances (receptor locations).

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Table C-14. Site Aggregate Chemical Inventory Screening Results

Chemical[1]	CAS number	Storage location [2] (Building)	Container Type	Aggregate Quantity [3] (pounds)
TOXIC SUBSTANCES				
Ammonia (TPQ = 500 lbs.)	7664-41-7	552	various size cylinders	1,155
		881	150 lb. cylinders	750
Chlorine (TPQ = 100 lbs.)	7782-50-5	124	150 lb. cylinders	900
		552	150 lb. cylinders	600
		995	150 lb. cylinders	900
Nitric Acid ~ 56% (TPQ = 1,000 lbs.)	7697-37-2	371/374 Complex	above ground storage tank	90,000
		771	inside building tanks	5,000
		910	inside building tanks	11,888
Sulfur Dioxide (TPQ = 500 lbs.)	7446-09-5	995	150 lb. cylinders	900
Sulfuric Acid (TPQ = 1,000 lbs.)	7664-93-9	443-outside	elevated storage tank	46,037
		771	above ground storage tank	5,727
		891	outside storage tank	27,775
FLAMMABLE SUBSTANCES				
Propane	74-96-6	P750 & P904	Tank Farms	32,714

Notes: Only chemicals exceeding the Sara Title III Threshold Planning Quantities are listed.
[1] Only chemicals in product form are included, waste stream chemicals are not included. All chemicals are pure unless otherwise indicated.
[2] Only single storage locations exceeding thresholds are listed in the Storage Location column.
[3] Inventory estimates are based on the RFETS Integrated Chemical Management System (ICMS) database inventory.

In a comparison of similar codes for determining chemical plume dispersion (Table C-15), the best code for the purpose of this analysis was determined to be ALOHA. Although, no code was found to be best in all cases, ALOHA was selected for the following reasons:

- ALOHA was developed, and additional studies funded by, the EPA, National Oceanic and Atmospheric Administration and National Safety Council to identify and document the codes strengths and weaknesses;
- Precedence; ALOHA has been employed in previous studies at the Site (Rocky Flats Environmental Technology Site, SARA Title III, "Facility Profile and Internal Contingency Plan"; EG&G 1995k)
- ALOHA contains an extensive database that results in consistent accident analysis; ALOHA has the ability to calculate dose concentrations at specific distances to receptors;
- ALOHA is readily available from the National Safety Council's Environmental Health Center at a reasonable cost;
- With ALOHA, it is relatively easy to duplicate the results utilizing the same conservative assumptions; and
- Most importantly, ALOHA models dense gas (i.e., chlorine).

FLAMMABLE SUBSTANCE RELEASE:

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The computer code chosen for computation of the effects of an UVCE was the Automated Resource for Chemical Hazard Incident Evaluation (ARCHIE) code developed jointly by the Federal Emergency Management Agency, the Department of Transportation, and the EPA. The code was developed to provide emergency planning personnel with the resources necessary to undertake comprehensive evaluations of potentially hazardous facilities and activities in order to formulate a basis for their planning efforts. The code requires input parameters to be specified for the specific material involved. User input includes the lower heat of combustion of the gas, the yield factor for the explosion, the weight of the flammable gas, and the location of the explosion relative to the ground surface. The model compares the combustion energy per unit mass of the vapor cloud of gas with that of TNT and takes into account that only a fraction (the yield factor) of the energy in the cloud will contribute to the explosion. Overpressure data compiled from measurements on TNT explosions are then used to relate overpressure, in psig, to distance from the explosion. The ARCHIE model produces a table which lists distances from the explosion center associated with various degrees of injury and damage to people and property. It is important to realize in the case of a UVCE that the center of the explosion could be anywhere within the area subjected to gas concentrations at or above the lower flammable level for the material of concern.

C-6.1.3 Health Effects Endpoints for Toxic Substance Releases

Potential exposure to toxic substances involves the dispersion and migration of the plume to receptor locations. An exposure endpoint is a quantifiable threshold at which a level of health effects or property damage may occur. The exposure endpoint is used to estimate the distance at which a certain level of health effect or damage may be reached. For toxic substances, the primary exposure hazard to the public is inhalation of vapor.

The consequences under consideration are the immediate health effects expected from a one-time acute exposure to a chemical resulting from an accidental release; rather than the potential consequences of long-term chronic exposure resulting from continuous releases. Ammonia, chlorine, sulfur dioxide, and nitric acid are not listed as potential carcinogens, and long-term cancer latency rate calculations are not applicable. Hazardous materials can pose toxic effects via three primary pathways of exposure: inhalation, ingestion, or direct contact with the skin or eyes. The exposure pathway of concern for this analysis is inhalation, which is the most sensitive route of exposure for individuals exposed to airborne substances.

Table C-15. Comparison of Computer Codes Available for Chemical Release Analysis

Name of Code	ARCHIE	CAMEO/ALOHA	EPI CODE
Developed by	FEMA/EPA/DOT	NOAA/EPA/NSC	Holmann Associates
Computers	IBM-PC	IBM-PC/Macintosh	IBM-PC
Past Use	Local Agencies, Sandia National Laboratories New Mexico and California	Local Agencies, Sandia National Laboratories New Mexico, Rocky Flats Environmental Technical Site	Sandia National Laboratories California, Lawrence Livermore National Laboratories
Application	Emergency Planning for hazardous material releases to meet SARA Title III requirements	Emergency Planning for hazardous material releases to meet SARA Title III requirements	Emergency Planning for hazardous material releases
Model Capabilities			
Chemical Database		X	X
Print Modeled Data	X	X	X
Save Modeled Data	X	X	X

Scenario Capability/Variables			
Source Strength			
User Specified	X	X	X
Calculated		X	
Emission Rates (Liquid/Gas)			
User Specified		X	X
Model Calculated	X	X	X
Liquid Pool Fire	X		
Flame Jet	X		
Plume (Vapor Cloud) Calc.	X	X	X
Tank	X	X	X
Pipe	X	X	X
Plume Behavior			
Puff	X	X	X
Plume	X	X	X
Fire Ball Radiation	X		
Solid/Liquid Explosion Hazard	X		
Dispersion Model Algorithms			
Dense Gas		X	
Gaussian/Neutrally Buoyant	X	X	X
Meteorological Conditions			
User Specified	X	X	X
Real Time		X	
Elevated Release	X	X	X
Ground Roughness		X	X
Boundary Conditions			
Surface Reflection		X	X
Mixing Lid		X	
Wind Field			
2 Dimensional	X	X	X
3 Dimensional			

Ammonia is a colorless gas with a penetrating suffocating odor. It is an eye, mucous membrane, and systemic irritant by inhalation. Section C-6.2.1 presents a characterization of ammonia.

Chlorine combines with moisture to form hydrochloric acid and is a primary irritant to the mucous membranes of the eyes, nose, throat, and linings of the entire respiratory tract. Broncheorestriction occurs immediately upon inhalation, resulting in dyspnea, the feeling of an inability to breathe (Sax 1989). Section C-6.2.1 presents a characterization of chlorine.

Sulfur dioxide is a poison gas mildly toxic to humans by inhalation. It chiefly affects the upper respiratory tract and bronchi. Section C-6.2.1 presents a characterization of sulfur dioxide.

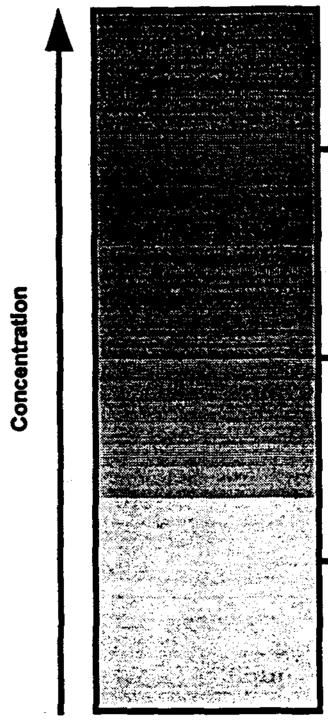
Nitric acid is corrosive to the eyes, skin, mucous membranes and teeth. It causes upper respiratory irritation which may seem to clear up only to return in a few hours and more severely. Depending on environmental factors the vapor will consist of a mixture of the various oxides of nitrogen and nitric acid (Sax 1989). Section C-6.2.1 presents a characterization of nitric acid.

Although propane can cause toxic health effects at high concentrations (the IDLH is 20,000 ppm), it is assessed here as a flammable/explosive substance and not as a toxic substance.

EMERGENCY RESPONSE PLANNING GUIDELINES. The consequences from accidental releases are estimated based upon airborne concentrations at various distances (receptor locations) from the accident location. This assessment includes the use of Emergency Response Planning Guidelines (ERPGs) to provide estimates of concentration ranges where one might reasonably expect to observe adverse effects from exposure to specific substances. The values derived for ERPGs are used for emergency planning purposes and are applicable to most individuals in the general population. The ERPG values are not regulatory exposure guidelines and do not incorporate the safety factors normally included in healthy worker exposure guidelines.

The ERPGs were developed by the American Industrial Hygiene Association to aid emergency planners and emergency responders in dealing with hazardous materials incidents (AIHA 1996). Figures C-1 and C-2 present additional information on ERPG values.

Figure C-1. Emergency Response Planning Guidelines (ERPG)



Chlorine

ERPG-3: (Life Threatening) — 20 ppm

The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing life-threatening health effects.

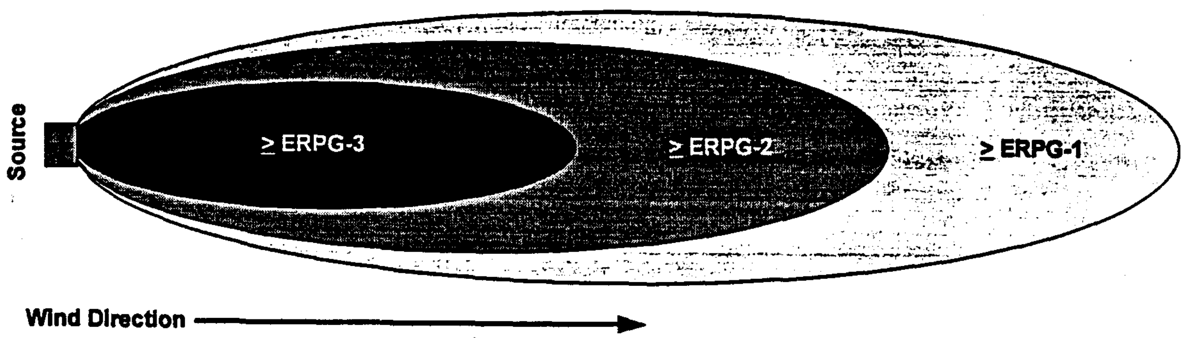
ERPG-2: (Irreversible) — 3 ppm

The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing or developing irreversible or serious health effects or symptoms that could impair an individual's ability to take protective action.

ERPG-1: (Reversible) — 1 ppm

The maximum airborne concentration below which it is believed that nearly all individuals could be exposed for up to one hour without experiencing other than mild, transient adverse health effects or without perceiving a clearly defined objectionable odor.

Figure C-2. Example Chemical Plume and Concentration Levels



A chemical plume emitted from a finite source decreases in concentration as the chemical is carried away from the source and dispersed by the wind.

Note: Chemical concentrations represented by shaded areas are greater than or equal to the indicated ERPG level.

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C-6.1.4 Receptor Descriptions

This analysis assessed the effects of an accidental release of toxic substances on three receptor groups. This allowed exposure estimates at various distances from the accident location. These receptor groups are defined as:

- Immediate Workers–an individual at 30 meters from the point of release assumed to be working at or within 30 meters of point of release. The immediate worker is assumed not to be wearing personal protective equipment, however, is expected to evacuate the accident scene;
- Collocated Workers–exposure assessments for collocated workers were conducted at 100 meters (328 feet) from the postulated point of release. Collocated workers are assumed not to be wearing personal protective equipment;
- Maximally Offsite Exposed Individuals (MOI) of the Public–a hypothetical member of the public who is located off-site at the nearest point of access to the point of release who would receive the largest exposure from a release.

In addition to these receptor locations, the distance to the ERPG concentrations were determined and presented to show the maximum distance at which individuals may be impacted.

For the propane release scenario, the receptor location is the distance to the endpoint at which personnel injury and damage to buildings could occur. The distance at which these effects occur is the distance to a one psig overpressure due to blast and shock waves.

C-6.2 Accident Scenarios Description

The accident scenarios under consideration for this analysis are: (1) an ammonia release from one-150 pound cylinder, (2) a chlorine release from 2-150 pound cylinders, (3) a sulfur dioxide release from two-150 pound cylinders, (4) a nitric acid (56% by weight) release from an above ground storage tank, and (5) a propane release from a 1,000 gallon propane tank and subsequent UVCE. The postulated chemical accident scenarios are discussed below and present in Table C-16.

AMMONIA RELEASE:

Building 881, a manufacturing and general support facility, utilizes ammonia in various rooms throughout the building. Each location has a single cylinder that may be uncapped to facilitate usage. A single cylinder is postulated to experience a failure (e.g., direct puncture, failure of the discharge valve, failure of piping/manifold, failure of the storage racks, piping failure, etc.) resulting in the release of the entire contents. This scenario results in the release of 150 pounds of ammonia from Building 881.

The postulated release height is conservatively assumed to be ground level. The complete release of the cylinder contents within a 10-minute time span is postulated resulting in a release rate of 15 lb/min. A 10-minute release is standard in emergency planning when modeling an instantaneous release. This is due to the conservatisms found in emergency planning models (e.g., ALOHA, ARCHIE, etc.). The distance to the MOI from Building 881 is assumed to be 1,788 meters (Ref. SSAR). This ammonia release scenario was modeled using average meteorological conditions and worst case meteorological conditions for the Site.

CHLORINE RELEASE:

Building 995, part of the Waste Water Treatment Plant (WWTP), utilizes two 150 pound chlorine cylinders connected by an automatic switch over valve at the process location where the gas is drawn for the chlorinating process. Both cylinders are postulated to experience a failure (e.g., direct puncture, failure of the discharge valve, failure of the switch over valve, failure of piping/manifold, failure of the storage racks, piping failure, etc.) resulting in the release of their entire contents. This scenario results in the release of 300 pounds of chlorine from Building 995.

The postulated release height is assumed to be ground level. The complete release of all cylinder contents within a 10-minute time span is postulated resulting in a release rate of 30 lb/min. The distance to the MOI from Building 995 is assumed to be 2,242 meters (Ref. SSAR). This chlorine release scenario was modeled using average meteorological conditions and worst case meteorological conditions for the Site.

SULFUR DIOXIDE RELEASE:

Sulfur dioxide is also utilized in the Building 995 waste water treatment processes. Two 150 pound cylinders of sulfur dioxide are connected by an automatic switch over valve at the process location where the gas is drawn into the process to remove chlorine. Both cylinders are postulated to experience a failure (e.g., direct puncture by structural debris, failure of the discharge valve, failure of piping/manifold, failure of the storage racks, foundation collapse, piping failure, etc.) resulting in the release of their entire contents. This scenario results in the release of 300 pounds of sulfur dioxide from Building 995.

The postulated release height is assumed to be ground level. The complete release of all cylinder contents within a 10-minute time span is postulated resulting in a release rate of 30 lb/min. This sulfur dioxide release scenario was modeled using average meteorological conditions and worst case meteorological conditions for the Site.

NITRIC ACID RELEASE:

The Building 371/374 outside nitric acid storage tank (designated as Tank D222) is postulated to experience a catastrophic failure. This scenario would result in a worst-case release of the entire contents of the tank, approximately 8,000 gallons of 56% by weight nitric acid solution into a bermed area around the tank. The berm around the tank is considered a passive mitigation feature and is credited in the analysis.

For the nitric acid release scenario, the nitric acid is stored in a 16,000 gallon capacity outside storage tank elevated above ground. The release scenario is postulated to involve the entire contents of the tank (8,000 gallons maximum, taking credit for administrative controls that limit inventory) and is assumed to be released instantaneously to form a liquid pool within the bermed area. The postulated release height is ground level. The distance to the MOI from the Building 371/374 Complex is assumed to be 1,580 meters (Ref. SSAR). The nitric acid release scenario was modeled using average meteorological conditions and worst case meteorological conditions for the Site.

PROPANE RELEASE:

The propane tank farms designated as P750 and P904 each contain eight-1,000 gallon propane tanks interconnected to a common manifold. For this release scenario it is postulated that one of the eight tanks catastrophically fails resulting in the release of 4,100 pounds of propane. The propane gas subsequently mixes with ambient air to form a vapor cloud that is in the flammable range within at least a portion of its volume. Ignition of the flammable mixture occurs with flame propagation through the flammable region of the cloud resulting in an overpressure condition.

Table C-16. Postulated Chemical Accident Scenarios

Release Scenario	Facility	Scenario Description
NH_3-01	Building 881	Release of 150 lb of ammonia (from one-150 pound cylinder) resulting from mechanical failure or physical damage to a cylinder under worst case meteorological conditions.
NH_3-02	Building 881	Release of 150 lb of ammonia (from one-150 pound cylinder) resulting from mechanical failure or physical damage to a cylinder under average meteorological conditions.
Cl-01	Building 995	Release of 300 lb of chlorine (from two-150 pound cylinders) resulting from mechanical failure or physical damage to cylinders under worst case meteorological conditions.
Cl-02	Building 995	Release of 300 lb of chlorine (from two-150 pound cylinders) resulting from mechanical failure or physical damage to cylinders under average meteorological conditions.
SO_2-01	Building 995	Release of 300 lb of sulfur dioxide (from two-150 pound cylinders) resulting from mechanical failure or physical damage to cylinders under worst case meteorological conditions.
SO_2-02	Building 995	Release of 300 lb of sulfur dioxide(from two-150 pound cylinders) resulting from mechanical failure or physical damage to cylinders under worst case meteorological conditions.
HNO_3-01	Building 371/374 Complex	Release of 90,000 lb of 56% by weight nitric acid resulting from a catastrophic failure of the outside nitric acid storage tank (D222) under worst case meteorological conditions.
HNO_3-02	Building 371/374 Complex	Release of 90,000 lb of 56% by weight nitric acid resulting from a catastrophic failure of the outside nitric acid storage tank (Tank D222) under average meteorological conditions.
Propane-01	P750 / P904	Release of 4,100 pounds of propane from a single 1,000 gallon tank at either the P750 or P904 propane tank farm and subsequent UVCE.

C-6.2.1 Material Characterization and Inventory Assumptions

The toxicity/health hazards associated with inhalation of ammonia, chlorine, sulfur dioxide, nitric acid, and propane are described here to support development of accident scenarios and analysis of possible consequences.

AMMONIA (CAS: 7664-41-7). Ammonia is a colorless gas with a penetrating, suffocating odor. It causes extreme irritation of the bronchial tissues when inhaled; continued inhalation destroys respiratory tissue, which causes respiratory and pulmonary diseases. Elevated blood ammonia concentrations may cause death by suffocation. Ammonia is detectable by odor at 5-10 ppm; results in general discomfort, eye tearing, and irritation of mucous membranes at 150-200 ppm; and is barely tolerable (danger of lung edema, asphyxia, and death within minutes) for more than a few moments, at concentrations of 2,000 ppm. Properties of ammonia are provided in Table C-17.

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Table C-17. Properties of Ammonia

Vapor Pressure	8.5 atm @ 20 °C
Boiling Point	-33 °C
Melting Point	-78 °C
Density (vapor)	0.6
OSHA PEL-TWA	50 ppm
ACGIH TLV-TWA	25 ppm (STEL 35 ppm)
ERPG-1	25 ppm
ERPG-2	200 ppm
ERPG-3	1,000 ppm
Flammability	Noncombustible
DOT Classification	Nonflammable Gas, Poison A

CHLORINE (CAS: 7782-50-5). Chlorine is a greenish-yellow, nonflammable gas that is toxic to humans by inhalation. Chlorine is not listed in the EPA Integrated Risk Information System (EPA 1995c) or the Health Effects Assessment Summary Tables (EPA 1995b) as a potential carcinogen. Human respiratory system effects by inhalation include changes in the trachea or bronchi, emphysema, chronic pulmonary edema, or congestion. Chlorine is a strong irritant to eyes and mucous membranes at 3 ppm. Chlorine combines with moisture to form hydrochloric acid. Both of these substances, if present in sufficient quantities, cause inflammation of the tissues with which they contact. A concentration of 3.5 ppm produces a detectable odor. A concentration to 15 ppm causes immediate irritations of the throat. Concentrations of 50 ppm are dangerous for even short periods of time, and concentrations of 1,035 ppm may be fatal (NIOSH 1991), even if the exposure is brief. Some studies indicate that some fatalities may result from a 30-minute exposure to 50-60 ppm. Because of its intensely irritating properties, severe industrial exposure seldom occurs, as the worker is forced to leave the exposure area before being seriously affected. Chlorine is a strong oxidizer and reacts with numerous other chemicals and metals and may cause explosive reactions. Based on the properties listed in Table C-18, chlorine behaves as a heavier than air dense gas when released as a vapor cloud (Lewis 1993).

Table C-18. Properties of Chlorine

Vapor Pressure	6.8 atm @ 20°C
Boiling Point	-34.05 °C
Melting Point	-101 °C
Density (vapor)	2.47
OSHA PEL-TWA	0.5 ppm
ACGIH TLV-TWA	0.5 ppm (STEL 1 ppm)
ERPG-1	1 ppm
ERPG-2	3 ppm
ERPG-3	20 ppm
Flammability	Noncombustible
DOT Classification	Nonflammable Gas, Poison A

SULFUR DIOXIDE (CAS: 7446-09-5). Sulfur dioxide is a poisonous gas that is mildly toxic to humans by inhalation. Human systemic effects by inhalation include: pulmonary vascular resistance, respiratory depression and other pulmonary changes. It affects the upper respiratory tract and the bronchi. It may cause edema of the lungs or glottis, and can produce respiratory paralysis. A corrosive irritant to eyes, skin, and mucous membranes. This material is so irritating that it provides its own warning of toxic concentration. At 400-500 ppm it is immediately dangerous to life. A concentration between 50-100 ppm is considered to be the maximum permissible concentration for exposures of 30-60 minutes. Excessive exposures to high concentrations of sulfur dioxide can be fatal. However, less than fatal concentrations can be borne for fair periods of time with no apparent permanent damage. Properties of sulfur dioxide are provided in Table C-19.

Table C-19. Properties of Sulfur Dioxide

Vapor Pressure	3.2 atm @ 20 °C
Boiling Point	-10 °C
Melting Point	-76 °C
Density (vapor)	2.3
OSHA PEL-TWA	5 ppm
ACGIH TLV-TWA	2 ppm (STEL 5 ppm)
ERPG-1	0.3 ppm
ERPG-2	3 ppm
ERPG-3	15 ppm
Flammability	Noncombustible
DOT Classification	Nonflammable Gas

NITRIC ACID (CAS: 7697-37-2).

Pure nitric acid is a colorless liquid. When commonly encountered, however, it is often yellow to red-brown in color, depending on the concentration of dissolved nitrogen dioxide. Nitric acid corrodes body tissue by reacting with complex proteins that make up the structure of tissues. Inhalation of vapors may cause nausea, vomiting, lightheadedness, head ache, severe irritation of the respiratory system, coughing, chest pains, difficulty breathing, or unconsciousness. Properties of nitric acid are provided in Table C-20.

Table C-20. Properties Nitric Acid (56% concentration)

Vapor Pressure	0.77mm @ 25 °C 1.076mm @ 30 °C
Boiling Point	120.5 °C
Specific Gravity	1.3449 @ 25 °C
OSHA PEL-TWA	2 ppm
ACGIH TLV-TWA	2 ppm (STEL 4 ppm)
ERPG-1 (equivalent)[1]	2 ppm
ERPG-2 (equivalent)[1]	15 ppm
ERPG-3 (equivalent)[1]	30 ppm
Flammability	Noncombustible liquid
DOT Classification	Corrosive material

[1] ERPG equivalent concentrations are taken from the *Rocky Flats Risk Assessment Guide* (EG&G 1994w)

PROPANE (CAS: 74-98-6).

At ambient conditions, propane is a colorless, odorless (may have odor added), and tasteless gas, but under moderate pressure, it is readily liquefied. Propane is a highly dangerous fire hazard when exposed to heat or flame and can react vigorously with oxidizers. It is explosive in the form of vapor when exposed to heat or flame. Propane can affect the central nervous system at high concentrations (the IDLH is 20,000 ppm) and is considered an asphyxiant. Based on the properties listed in Table C-21, propane behaves as a heavier than air dense gas when released as a vapor cloud.

Table C-21. Properties of Propane

Vapor Pressure	8.4 atm @ 70 °F
Boiling Point	-45 °C
Melting Point	-187 °C
Specific Gravity	0.58
Density (vapor)	1.55
Specific Gravity	0.5077 @ 20 °C
Flash Point	-104 °C
Lower Explosive Limit	2.1%
Upper Explosive Limit	9.5%
DOT Classification	Flammable Gas

INVENTORY ASSUMPTIONS. Information relating to the types and quantities of chemicals stored on-site and storage locations was obtained from the Site *Facility Profile and Internal Contingency Plan* (EG&G 1995k) and the site ICMS database. Table C-22 presents a list of ammonia, chlorine, sulfur dioxide, nitric acid, and propane inventories and storage locations.

Analysis of the ammonia, chlorine, and sulfur dioxide releases were conducted considering the greatest amount held in a single vessel or held in multiple vessels that are interconnected. For ammonia, the release amount was assumed to be 150 pounds, in a single "active" cylinder. For chlorine and sulfur dioxide, the release amount was assumed to be 300 pounds in two "active" 150 pound cylinders interconnected to a common manifold.

Analysis of the nitric acid release was conducted assuming the greatest amount held in a single vessel. The largest vessel containing nitric acid was determined to be Tank D222 outside the Building 371/374 Complex. The capacity of this tank is 16,000 gallons, however, the current inventory is approximately 50% or 8,000 gallons. The inventory in the tank will be administratively controlled not to exceed 50% capacity.

Analysis of the propane explosion was conducted by considering the greatest amount held in a single vessel within the tank farms which is consistent with the 40 CFR 68 hazard assessment methodology for flammable substances.

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Table C-22. Inventories Involved in Postulated Release Scenarios

Hazardous Substance	Initiating Event	Inventory	Location
Ammonia	Cylinder failure due to mechanical failure or physical damage	150 lb	Building 881
Chlorine Gas	Cylinder failure due to mechanical failure or physical damage	300 lb	Building 995
Sulfur Dioxide	Cylinder failure due to mechanical failure or physical damage	300 lb	Building 995
Nitric Acid Mixture	Catastrophic tank failure	90,000 lb	Outside Building 371/374 Complex
Propane	Catastrophic tank failure	4,100 lb	Tank Farms P750 and P904

C-6.2.2 Release Factors

RELEASE SCENARIOS NH_3-01, NH_3-02, CL-01, CL-02, SO_2-01, AND SO_2-02. Cylinder failure could occur through a variety of means (e.g., direct puncture, failure of the discharge valve, failure of piping, failure of the storage racks, piping failure, etc.). Therefore, a release fraction (percentage of material released) of 100% is used. Since the ammonia, chlorine, and sulfur dioxide are released in a gaseous state, all available inventory is respirable; therefore, a respirable fraction of 1 is used. This results in an aggregated release of 150 pounds for the ammonia scenario and 300 pounds for the chlorine and sulfur dioxide scenarios in the form of an airborne plume.

RELEASE SCENARIOS NITRIC-01 AND NITRIC-02. The initiating event is defined as a catastrophic failure of Tank D222 outside of the Building 371/374 Complex. Due to the magnitude of the postulated initiating event, it is assumed that no engineered safety features of the tank system will survive. Therefore, a release fraction (percentage of material released) of 100% is used. However, the actual amount of nitric acid that volatilizes to the atmosphere was determined based on the surface area of the spill which is limited by the size of the berm around the tank.

RELEASE SCENARIO PROPANE-01. The initiating event is defined as a catastrophic failure of one of the eight-1,000 gallon propane tanks at either of two tank farms (P750 and P904). For this release scenario, the quantity of propane involved in the UVCE is assumed to be 100% of the total amount released.

C-6.2.3 Model Parameters and Assumptions

For toxic releases, receptor locations were modeled for on-site distances of 30 meters for the immediate worker and 100 meters for the collocated worker. In addition, the distance to the MOI was modeled to determine the consequences to the public. To add conservatism to the estimate of consequences, human receptors were assumed to be located outdoors and at the plume centerline. In addition, average Site wind directions were not used, allowing for the use of wind directions that would represent the worst possible off-site consequences.

To keep the analyses of these accidents within the realm of reason, the scenarios use conservative assumptions, such as moderately stable meteorological conditions that reduce the downwind dilution of hazardous material releases, or ignore the tendency for reactive chemicals to be depleted by reaction. In addition, the analysis scenarios do not violate physical principles or take credit for mitigating factors that would prevent a release.

For the propane explosion scenario, it was also assumed that the entire quantity of propane released (4,100 pounds) is in the vapor cloud and that the vapor cloud detonates. A 0.03 (3%) yield factor was assumed to estimate the distance to the explosion endpoint. This assumption provides a conservative estimation of the distance to the explosion endpoint. In a vast majority of cases, the VCE will propagate as a deflagration (detonation throughout an entire vapor cloud is extremely rare) and the distance to the explosion endpoint of one psig would be less.

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C-6.2.4 Meteorological Parameters

To model the atmospheric transport of a toxic substance release from the Site, site-specific meteorological data were used. The assumptions about atmospheric conditions are similar to those used in the analysis of radioactive material releases; however, the ALOHA code uses a simplified version of meteorological data as compared to the MACCS radiological code. The average meteorological conditions used for the chemical accident analysis were wind speed of 4.5 meters per second; Pasquill-Gifford stability class D (neutral conditions); an ambient temperature of 50∞F; and relative humidity of 43%.

To ensure the analysis is conservative, employment of "worst case"(moderately stable) meteorological conditions were also utilized giving rise to minimal plume dispersion, thus, resulting in the greatest postulated consequences. The following "worst case" meteorological conditions were used in this analysis: wind speed of 2 meters per second; Pasquill-Gifford stability class F (moderately stable); an ambient temperature of 50∞F; and relative humidity of 43%. Worst case conditions were assumed in calculating the effects of a release, so no wind frequency data were used in the calculation of concentrations from an accidental release. During accident conditions, no wind direction was selected so that 100% of the released material was conveyed to all identified potential receptors. This method is conservative in the fact that it allows for employment of wind directions that would estimate the worst off-site consequences.

C-6.2.5 Dispersion Parameters - Toxic Releases

The consequences resulting from an exposure to an airborne chemical at a specific receptor location are dependent upon the toxicity and quantities of materials released and the impact that the local environment may have on the plume's dispersion. Atmospheric dilution depends on the height of the release and the environmental conditions traversed between the release point and the receptor. Atmospheric dispersion models can describe transport and turbulent diffusion of chemicals released for the selected meteorological conditions, depletion of the plume as a result of deposition onto surfaces, and wash-out due to precipitation.

The selection of a dispersion model for a specific application is based on the intended use, characteristics of the chemical, and available meteorological conditions. Simplified atmospheric models are appropriate for the estimation of potential doses. This is because the releases are hypothetical, the receptors are not in the immediate vicinity of the release, and the evaluation is based on assumed meteorological conditions.

The toxic release scenarios were analyzed employing both the "average" (4.5 meters per second wind speed with a stability class of D) and "worst case" meteorological conditions (1.5 meters per second wind speed with a stability class of F). To predict the dispersion of chlorine and nitric acid, ALOHA employs a heavier than air calculation model.

Another parameter that contributes to dispersion is surface roughness. Roughness elements are any surface feature that interrupts the flow of air and contributes to mixing of the air. A surface roughness of 3 cm (designated as "open country" by ALOHA) was conservatively applied to ALOHA when modeling for releases of toxic substances. This feature allows model operators to take credit for the deposition and dilution of more or less materials based on the presence or absence of building and/or forest-induced turbulence and friction. The wind was assumed to be in the direction of the nearest offsite receptor.

C-6.2.7 Exposure Quantification

In addition to evaluation of toxic substance exposures using ERPG values (or equivalent), other exposure quantifications were considered in this analysis. However, ammonia, chlorine, sulfur dioxide, and nitric acid are not listed in the EPA Integrated Risk Information System Index or the Health Effects Assessment Summary Tables as a carcinogen. Therefore, calculation of incremental cancer risk is not applicable.

The measure used to describe the potential for noncarcinogenic toxicity to occur in an individual is not expressed as the probability of an individual suffering an adverse effect (EPA

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1989a). The Environmental Protection Agency does not at the present time use a probabilistic approach to estimating the potential for noncarcinogenic health effects. Instead, the potential for noncarcinogenic effects is evaluated by comparing an exposure level over a specified time period with a reference dose derived for a similar exposure period. This ratio of exposure to toxicity is called a hazard quotient and is described as:

Hazard Quotient = E/RfD (E = Exposure Level (ppm)/RfD = Reference Dose)

As previously stated, ammonia, chlorine, sulfur dioxide, and nitric acid are not listed as carcinogens. In addition, no reference dose is listed for ammonia, chlorine, sulfur dioxide or nitric acid. For this analysis, the ERPG-1 values (or equivalent) for ammonia (25 ppm) chlorine (1 ppm), sulfur dioxide (0.3 ppm), and nitric acid (2 ppm) were used as the reference doses.

The noncancer hazard quotient assumes that there is a level of exposure (i.e., reference dose) below which it is unlikely for even sensitive populations to experience adverse health effects. The noncancer hazard quotient is commonly used for chronic and subchronic exposures. For shorter-term exposures (less than two weeks), chemicals known to be developmental toxicants can be of concern. However, no cancer or pathological changes have been reported for chlorine and nitric acid (NIOSH 1976).

For hazardous materials, several governmental agencies recommend quantifying health effects as threshold values of concentrations in air or water that cause short-term effects. The long-term health consequences of exposure to hazardous materials are not as well understood as those for radiation. Thus, the potential health effects reported here for hazardous materials are more qualitative than for radioactive materials. ERPG values (or equivalents) are used in this analysis to provide estimates of concentration ranges above which one can reasonably anticipate observing adverse health effects.

C-6.3 Estimated Impacts -Toxic Releases

This section describes the potential health consequences of the ammonia, chlorine, sulfur dioxide, and nitric acid accident scenarios. The results are presented in terms of the three ERPG concentrations, at distances to the receptors identified previously. The exposures were determined separately for each postulated accident scenario. During accident conditions, no specific wind direction was selected so that 100% of the released material was conveyed to all potential receptors regardless of direction from the release point. In all cases, evacuation of personnel per emergency response procedures will reduce the exposure duration and, therefore, the potential health impacts described in subsequent paragraphs of this section. Table C-23 presents a listing of impacts to identified receptors by release scenario.

C-6.3.1 Impacts to Immediate Workers

Immediate workers are assumed to be working at or within 30 meters of the point of release. The concentrations of ammonia at 30 meters range from 4,980 to 8,110 ppm based on the assumed meteorological conditions. These concentrations exceed the ERPG-3 endpoint of 1,000 ppm and are potentially *life threatening* to the immediate worker.

Death from exposure to chlorine has been reported following a five-minute exposure to chlorine concentrations of 1,035 ppm (NIOSH 1991). While the immediate worker may be assumed to be among the fatalities resulting from the initiating event, concentrations of chlorine at 30 meters range from 1,730 to 3,440 ppm based on the assumed meteorological conditions. These concentrations exceed the ERPG-3 endpoint of 20 ppm and are potentially *life threatening* to the immediate worker.

For the sulfur dioxide release scenario, the concentrations at 30 meters range from 1,830 to 3,650 ppm based on the assumed meteorological conditions. These concentrations exceed the ERPG-3 endpoint of 15 ppm and are potentially *life threatening* to the immediate worker.

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For the nitric acid release scenario, the concentrations at 30 meters range from 46 to 141 ppm based on the assumed meteorological conditions. These concentrations exceed the ERPG-3 endpoint of 30 ppm and are potentially *life threatening* to the immediate worker.

C-6.3.2 Impacts to Collocated Workers

Collocated workers are assumed to be 100 meters from the point of release. The concentrations of ammonia at 100 meters range from 548 to 990 ppm based on the assumed meteorological conditions. These concentrations exceed the ERPG-2 endpoint of 200 ppm and present potentially *irreversible* health effects to the collocated worker. The actual distances to the ERPG-2 toxic endpoint are either 170 meters or 282 meters depending on the assumed meteorological conditions. Based upon the distances to the ERPG-2 endpoint, workers located beyond the 100 meter distance could also suffer *irreversible* health effects.

The concentrations of chlorine at 100 meters from the point of release range from 235 to 376 ppm based on the assumed meteorological conditions. These concentrations exceed the ERPG-3 endpoint of 20 ppm and are potentially *life threatening* to the collocated worker. The actual distances to the ERPG-3 toxic endpoint are 394 meters or 664 meters depending on the assumed meteorological conditions. Based upon the distances to the ERPG-3 endpoint, workers located beyond the 100 meter distance could also be exposed to *life threatening* concentrations of chlorine.

For the sulfur dioxide release scenario, the concentrations at 100 meters range from 276 to 405 ppm based on assumed meteorological conditions. These concentrations exceed the ERPG-3 endpoint of 15 ppm and are potentially *life threatening* to the collocated worker. The actual distances to the ERPG-3 endpoint are 480 meters or 847 meters depending on the assumed meteorological conditions. Based upon the distances to the ERPG-3 endpoint, workers located beyond the 100 meter distance could also be exposed to *life threatening* concentrations of sulfur dioxide.

For the nitric acid release scenario, the concentrations range from 4 to 18 ppm based on the assumed meteorological conditions. The 18 ppm concentration exceeds the ERPG-2 concentration of 15 ppm and presents potentially *irreversible* health effects. The 4 ppm concentration exceeds the ERPG-1 concentration of 2 ppm and presents potentially *reversible* health effects.

C-6.3.3 Impacts to Maximally Offsite Exposed Individuals of the Public

The Maximally Offsite Exposed (MOI) Individual of the Public is assumed to be located at the nearest off-site location from the point of release. The MOI distance is 1,788 meters from Building 881 for the ammonia release; 2,242 meters from Building 995, for the chlorine and sulfur dioxide releases; and 1,580 meters from Building 371/374 Complex, for the nitric acid release.

For the ammonia release scenario, the MOI would potentially be exposed to concentrations less than the ERPG-1 endpoint of 25 ppm (regardless of the assumed meteorological conditions) resulting in only *mild* health effects.

For the chlorine release scenario, the MOI would potentially be exposed to concentrations that range from 0.7 to 3.1 ppm based on assumed meteorological conditions. The 3.1 ppm concentration barely exceeds the ERPG-2 endpoint of 3 ppm and presents potentially *irreversible* health effects. The 0.7 ppm concentration is less than the ERPG-1 endpoint of one ppm and presents only *mild* health effects.

For the sulfur dioxide release scenario, the MOI would be potentially exposed to concentrations that range from 0.8 to 3.3 ppm based on assumed meteorological conditions. The 3.3 ppm concentration exceeds the ERPG-2 endpoint of 3 ppm and presents potentially *irreversible* health effects. The 0.8 ppm concentration exceeds the ERPG-1 endpoint of 0.3 ppm and presents potentially *reversible* health effects.

Table C-23 Estimated Impacts for Toxic Substance Releases

		150 lb NH_3 (worst case meteorology)	150 lb NH_3 (average meteorology)	300 lb Cl (worst case meteorology)	300 lb Cl (average meteorology)	300 lb SO_2 (worst case meteorology)	300 lb SO_2 (average meteorology)	50,000 lb HNO_3 (worst case meteorology)	50,000 lb HNO_3 (average meteorology)
Maximum Distance To:	ERPG-1	1.1 km	516 m	3.9 km	1.9 km	6.6 km	3.7 km	338 m	145 m
	ERPG-2	282 m	170	2.3 km	1.1 km	2.3 km	1.1 km	111 m	53 m
	ERPG-3	99 m	72 m	661 m	386 m	847 m	480 m	76 m	36 m
Maximum Consequences									
Immediate Worker (30 m)	Parts per million (ppm)	8,110	4,980	3,440	1,730	3,650	1,830	141	46
	Level of Concern	> ERPG-3	> ERPG-3	> ERPG-3	> ERPG-3	> ERPG-3	> ERPG-3	> ERPG-3	> ERPG-3
	Potential Health Effects	**Life Threatening**	**Life Threatening**	**Life Threatening**	**Life Threatening**	**Life Threatening**	**Life Threatening**	**Life Threatening**	**Life Threatening**
Collocated Worker (100 m)	Parts per million (ppm)	990	548	376	235	405	276	18	4.2
	Level of Concern	> ERPG-3	> ERPG-3	> ERPG-3	> ERPG-3	> ERPG-3	> ERPG-3	> ERPG-3	> ERPG-3
	Hazard Quotient	40	22	376	235	1350	920	9	2.1
	Potential Health Effects	**Irreversible**	**Irreversible**	**Life Threatening**	**Life Threatening**	**Life Threatening**	**Life Threatening**	**Irreversible**	**Reversible**
Maximally Offsite Exposed Individuals [1]	Parts per million (ppm)	11	2.4	3.1	0.7	3.3	0.8	0.1	0.02
	Level of Concern	> ERPG-2	> ERPG-2	> ERPG-2	> ERPG-2	> ERPG-2	> ERPG-2	> ERPG-2	> ERPG-2
	Hazard Quotient	0.4	0.1	3.1	0.7	11	2.7	0.05	0.01
	Potential Health Effects	**Mild**	**Mild**	**Irreversible**	**Mild**	**Irreversible**	**Reversible**	**Mild**	**Mild**

[1] The MOI distances are as follows: 1,788 meters for the ammonia scenario, 2,242 meters for chlorine and sulfur dioxide scenarios, and 1,580 meters for the nitric acid scenario.

For the nitric acid scenario, the MOI would potentially be exposed to concentrations less than the ERPG-1 endpoint of 2 ppm (regardless of the assumed meteorological conditions) resulting in only *mild* health effects.

C-6.4 Estimated Impacts - Propane Release/UVCE

This section describes the potential effects of an UVCE of propane. The distance to a one psig overpressure, which could result in surrounding building damage and injury to personnel, is 136 meters. There are three nuclear facilities, two radiological facilities, and four industrial facilities/areas located within a 136 meter radius of the P750 or P904 propane tank farm locations. These facilities are listed below:

- The 750 Pad, Storage Pad - Pondcrete, classified as a Category 3 Nuclear Facility
- The 750 Trailer Area, Office Trailers, Classified as Industrial Facilities
- Building 765, Secondary Alarm Center, classified as an Industrial Facility
- Building 903A, Main Decontamination Facility, classified as a Radiological Facility
- Building 903B, Decontamination Support Facility, classified as an Industrial Facility
- Building 892, RCRA Storage Unit 18.04, classified as a Radiological Facility
- The 903 Pad, Radiological Pad, classified as a Category 3 Nuclear Facility
- Building 906, Centralized Waste Storage, classified as a Category 3 Nuclear Facility
- The 891 Trailer Area, Offices Trailers, classified as Industrial Facilities

A radiological material release from any of the Category 3 Nuclear Facilities within the 136 meter radius, due to an UVCE of propane, are bounded by accident scenarios analyzed in the Authorization Basis (AB) documents for these facilities. For the radiological facilities, the radiological material-at-risk (MAR) is assumed to be below quantities that would present unacceptable consequences to the collocated worker or public if released. Personnel injury could potentially occur at each of the locations within the 136 meter radius. Table C-24 summarizes the UVCE effects.

Table C-24. Propane Unconfined Vapor Cloud Explosion Effects

Overpressure (psig)	Distance From Explosion (m)	Expected Damage
.03	2,589	Occasional breakage of large windows under stress.
.30	365	Some damage to home ceilings; 10% window breakage.
1.0 (Explosion Endpoint)	*136*	***Partial demolition of homes, made uninhabitable, knocks individuals off their feet.***
2.0	82	Partial collapse of home walls/roofs.
2.5	71	50% destruction of home brickwork.
5.0	46	Wooden utility poles snapped.
10	31	Probable total building destruction.

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C-6.5 Accident Mitigation Activities

An important part of the accident analysis process is to identify actions that can mitigate consequences from accidents if they occur. This section summarizes the Site emergency plan and the engineered safety features of facilities in which a chemical accident could occur. Building 995, Building 371/374 outside storage tank system, and the P750/P904 tank farms are reviewed.

C-6.5.1 Summary of the Site Emergency Response Plan

The Site emergency plan (EG&G 1995b) establishes the concepts for preparedness and response to operational emergencies by defining the roles and responsibilities of the Site Emergency Response Organization. As defined in DOE Order 151.1, an EMERGENCY is a significant accident, incident, event, or natural phenomenon that seriously degrades the safety or security of Department of Energy facilities. EMERGENCIES are classified as an ALERT or higher. The Site Emergency Plan details the protective actions that limit the adverse impacts to the Site workers, public, and environment. It specifies the provisions for response, communications, mitigation, and recovery whenever a responsible authority declares an EMERGENCY situation. (The plan can also be activated when conditions exists that could result in an emergency, at the discretion of the responsible authority, without the declaration of an actual EMERGENCY.) In addition, the interfaces and coordination with off-site government agencies and organizations regarding their response to a Site EMERGENCY are outlined.

The Emergency Plan is based on the assessments of events that can lead to an EMERGENCY at the Site. This planning addresses the preparedness, response, and mitigation activities that would be required in the event of an EMERGENCY.

- Fires and explosions,
- Hazardous and radioactive material releases,
- Nuclear criticality,
- Security-related events (e.g., threats to SNM, bomb threats, civil disturbances),
- Nuclear Material Safeguards related events,
- Threats to vital equipment,
- Transportation accidents, and
- Adverse natural phenomena.

Because these events require an increased alert status for on-site personnel and, in specified cases, for off-site authorities, EMERGENCIES are classified at one of three levels for uniform significance. In accordance with DOE Order 0 151.1, EMERGENCIES are classified as *either ALERT, SITE AREA EMERGENCY, or GENERAL EMERGENCY* in ascending order of severity. Each level has associated chemical ERPG or radiological Protective Action Guides exposure levels, beyond which prescribed protective actions should be considered. Protective Actions are intended for the general public or general Site population and do not include the use of protective gear or exposure guidelines used by emergency response teams. Examples of protective actions include evacuating or sheltering personnel to prevent adverse health effects from exposure to hazardous materials released to the environment.

Protective actions are based on the worst-case assumption that little-to-no advanced warning is received. Airborne toxins or contaminants are assumed to move downwind so rapidly that no time is available to communicate the need for evacuation to personnel other than the immediate workers. Sheltering in place will normally provide the lowest possible exposure for the general on-site population and therefore, is the default protective action of choice. Individual Building Emergency Plans describe the specific methods developed for protection, evacuation, and accountability of building personnel.

C-6.5.2 Summary of the Engineered Safety Features

Sound principles of nuclear and industrial safety govern the activities at the Site and the design of its processes and facilities. Site buildings utilize numerous special mechanical and design features to confine or control hazardous materials. Features such as walls, gloveboxes, barriers, filters, protective coatings, liners, safe containment vessels, safety equipment, and shielding combine to restrict the hazardous materials to areas specifically designed to contain them. However, while engineered safety features (e.g., filtered ventilation and structural containment) are a common and even required practice for facilities with processes involving radioactive materials the same practices are not always employed for facilities containing chemicals. Therefore, no engineered safety features for chemicals are present in facilities that contain chlorine at the Site, thus, no additional barriers are present that could mitigate the release and/or consequences of an accident.

From a review of common mode initiators (external, internal, and natural phenomena), it was determined that a chlorine release could originate from Buildings 124 (this would be postulated as a 150 pound release) and 995. These facilities and their safety features are briefly discussed below.

<u>BUILDING 124.</u> Building 124 is a water treatment plant that has been in use since June 1953. Its exterior and interior walls, floors, and roof are all constructed of concrete. For emergency power, the building has a 225 kW diesel-powered generator with a 500-gallon fuel tank. Automatic sprinklers are located only in the basement generator room. Hand extinguishers and manual fire alarm transmitters are located throughout the building. No engineered safety features, other than the structure, are present in this facility that could mitigate the release of chlorine and/or consequences of an accident.

<u>BUILDING 881.</u> Building 881 is a two story and basement building built into a hillside and mostly below grade. The exterior walls of the building are concrete with steel frame construction, and the interior walls are concrete, concrete block, gypsum board, or transite. The floors are concrete. The ceilings are primarily suspended acoustical tile. Some rooms have metal pan or exposed concrete ceilings. The roof is build-up roofing with foamglass insulation over concrete and metal deck. The building is equipped with HEPA filtration and has 90 chemical hoods located throughout. No engineered safety features, other than the structure, are present in this facility that could mitigate the release of ammonia and/or consequences of an accident.

<u>BUILDING 995.</u> Building 995 is a Sewage Treatment Plant for sanitary waste water generated throughout the Site. The exterior walls, floors, and roof are constructed of concrete. Hand fire extinguishers are present. No emergency power supply exists. No engineered safety features, other than the structure, are present in this facility that could mitigate the release of chlorine or sulfur dioxide and/or consequences of an accident.

<u>BUILDING 371/374 COMPLEX TANK SYSTEM</u>. Since the nitric acid release is assumed to result from a catastrophic failure of the tank, no design features of the tank system are credited to prevent the accident from occurring. Credit is taken for the earthen berm around the tank to passively mitigate a release of nitric acid by limiting the pool size and reducing the evaporation rate as compared to a unconfined release of the same quantity of nitric acid.

<u>P750/P904 PROPANE TANK FARMS.</u> Each of the eight-1,000 gallon horizontal steel tanks are mounted on a common concrete pad, are self supported, and are tied down to the concrete

foundations with wire rope. Tanks are rated for a working pressure of 250 psi and each is equipped with a 3/4 inch relief valve, also rated at 250 psi. An isolation valve is provided in the discharge lines between the tanks and the manifold. There is a main isolation valve on the manifold between each tank farm and its vaporizer. Since the propane release is assumed to result from a catastrophic failure of one of these tanks, no design features of the tanks are credited to prevent the accident from occurring. In addition, there are no mitigation features credited for a single tank release.

C-6.6 Chemical Impacts - *Closure* Case

This section addresses the effects of the postulated accident scenarios as they would change during a 10-year timeframe.

Chlorine and sulfur dioxide usage in Building 995 is expected to be eliminated by the end of 1997 thus eliminating the potential release scenarios from this Building. The only other building that utilizes chlorine in a process is Building 124 at the Water Treatment Plant. One cylinder is active in the process at a given time with additional cylinders staged in storage (in an approved storage rack, chained, with valve caps in place). Therefore, the chlorine release scenario becomes a 150 pound release from a single cylinder located in Building 124. Table C-52 presents a listing of impacts to the immediate worker, collocated worker, and MOI for this revised chlorine release scenario.

The only other building that utilizes sulfur dioxide in a significant quantity is Building 881. However, the total building quantity (approximately 300 pounds) does not exceed the screening thresholds used in this analysis and therefore a release was not postulated.

The current inventory of nitric acid in the outside storage tank at the Building 371/374 Complex is expected to meet the current and future building needs without procuring additional quantities. As a result, the consequences of the postulated nitric acid release will continue to be reduced as the inventory is utilized.

The site propane inventory is also expected to decrease as the demand is reduced. However, the scenario that is postulated here will remain as a realistic scenario as long as any of the eight tanks at either propane tank farm are used for storage.

Table C-25. Estimated Impacts for Chlorine Release - *Closure* Case

		150 lb Cl (worst case meteorology)	150 lb Cl (average meteorology)
Maximum Distance To:	ERPG-1	2.9 km	1.3 km
	ERPG-2	1.6 km	756 m
	ERPG-3	485 m	275 m
Maximum Consequences			
Immediate Worker (30 m)	Parts per million (ppm)	1,760	1,040
	Level of Concern	> ERPG-3	> ERPG-3
	Potential Health Effects	**Life Threatening**	**Life Threatening**
Collocated Worker (100 m)	Parts per million (ppm)	219	131
	Level of Concern	> ERPG-3	> ERPG-3
	Hazard Quotient	219	131
	Potential Health Effects	**Life Threatening**	**Life Threatening**
Maximally Offsite Exposed Individuals (1,068 m)	Parts per million (ppm)	6.2	1.6
	Level of Concern	> ERPG-2	> ERPG-2
	Hazard Quotient	6.2	1.6
	Potential Health Effects	**Irreversible**	**Reversible**

C-7 Occupational Injuries and Illnesses

C-7.1 Occupational Health Impact Analysis

Section 4.8.3, "Nonradiological Impacts on Worker Health and Safety," describes the methodology and results that were used to predict reportable cases as defined by the OSHA for the *Baseline* and *Closure* Cases. The purpose of this appendix is to present data used for these analyses, to provide additional description of some of the terms that were used in that analysis, and to further describe some of the new activities that would take place at the Site with their associated hazards. Raw data that were used as the basis for the analysis are included in the Technical Support Document prepared for the draft Sitewide Environmental Impact Statement that has not been finalized.

Data summarizing reportable cases of occupational illnesses and injuries among contractor employees were collected from annual OSHA 200 log summaries for years 1990 through 1994. Similar information was obtained from the Site Occupational Safety department for subcontractor employees. These data are presented in the following tables: Table C-26 summarizes projected plant population data under the *Baseline* and *Closure* Cases and applies appropriate incidence rates to estimate the number of annual incidences that would occur for the *Baseline* and *Closure* Cases; Table C-27 presents the data that were used to calculate incidence rates for contractor and subcontractor employees and construction activities; Table C-28 calculates the distribution of illness cases among OSHA illness categories over the years 1990-1994.

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Table C-26. Estimated Annual Injury and Illness Cases

Site Population by Organization	*Baseline* Case 1994	*Closure* Case Peak	*Closure* Case 2006
Engineering & Safety Services	1,615	1,806	1,615
Administrative Services	759	794	759
Analytical Services	342	394	342
Support Services	1,451	1,590	1,451
Environmental Restoration	197	246	246
Waste Stabilization/Treatment	400	480	480
Waste Management/Storage	513	616	616
SNM Management	127	191	102
Economic Development	209	209	669
DD&D	145	218	218
Extended Absences	15	15	15
Office of the President	452	452	452
Total Site Contractor Employees	**6,225**	**7,011**	**6,965**
Total Site Contractor Hours	**13,810,159**	**14,022,000**	**13,930,000**
Total Contractor Cases	**284**	**351**	**348**
Subcontractors	**2,133**	**2,666**	**2,455**
Total Subcontractor Hours	**372,776**	**533,200**	**491,000**
Total Subcontractor Cases	**20**	**36**	**33**
Total Population Including Subcontractors	**8,358**	**9,677**	**9,420**
Total Cases Including Subcontractors	**304**	**387**	**382**

Assumptions: 1) Contractor and subcontractor employees work 2,000 hours per year.
Incidence rates (reportable cases per 200,000 hours worked):
- 5.0 for contractor employees
- 5.3 for subcontractor employees under *Baseline* Case based on Site history
- 13.6 for subcontractor employees under *Closure* Case based on construction rates

2) DOE employees are not included; no cases were attributed to this group in historical data.

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Table C-27. Incidence Rates at the Site and General Industry

Year	Number of Injuries	Number of Illnesses	Total Cases[1]	Total Hours Worked[2]	Incidence Rate per 200,000 Work-Hours
Contractor Rates					
1990	347	53	400	12,956,146	6.2
1991	344	51	395	14,597,720	5.4
1992	297	78	375	15,991,820	4.7
1993	274	88	362	14,806,593	4.9
1994	204	80	284	13,810,159	4.1
Total	**1,466**	**350**	**1,816**	**72,162,438**	**5.0**
Subcontractor Rates					
1990	11	1	12	928,543	2.6
1991	7	0	7	1,125,436	1.2
1992	15	0	15	740,333	4.1
1993	40	1	41	388,632	21.1
1994	20	0	20	372,776	10.7
Total	**93**	**2**	**95**	**3,555,720**	**5.3**
Construction Trade Rates[3]					
1988					14.6
1989					14.3
1990					14.2
1991					13
1992					13.1
1993					12.2
Average					**13.6**

[1]Data for contractor employees derived from annual OSHA 200 Log (EG&G 1994k) provided by Site Occupational Health and Safety department; subcontractor data provided by Site Occupational Safety (EG&G 1994m).
[2]Data provided by Site Central Planning department.
[3]Department of Labor. *Survey of Occupational Injuries and Illnesses* (USDL 1993b).

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Table C-28. Distribution of Illness Cases Among Occupational Safety and Health Illness Categories for Site Contractor Employees

Categories for Occupational Illnesses	1990	1991	1992	1993	1994	1990-1994	Average	Percent of Illnesses
Occupational Skin Disorders (contact dermatitis, chemical burns)	26	18	25	24	21	114	22.8	32.6
Dust diseases (silicoses, asbestosis)	7	3	2	2	1	15	3.0	4.3
Respiratory condition due to toxic agents (pneumonitis due to chemicals, gases, dust)	2	3	5	3	3	16	3.2	4.6
Poisoning (metal poisoning, CO, H_2S, organic solvents, pesticides)	0	0	0	2	0	2	0.4	0.6
Disorders due to physical agents (heat and cold stress, radiation)	0	2	1	14	9	26	5.2	7.4
Disorders associated with repeated trauma (repetitive trauma disorders, hearing loss)	14	25	45	43	46	173	34.6	49.4
All other occupational illnesses (infectious hepatitis, food poisoning)	4	0	0	0	0	4	0.8	1.1
Total	**53**	**51**	**78**	**88**	**80**	**350**	**70.0**	**100.0**

C-7.2 Description of OSHA Illness Categories

Occupational injuries and illnesses are defined specifically by the OSHA (USDL 1993b). In addition the OSHA has divided the illness category of reportable cases in seven subcategories. The predominance of these subcategories was discussed in Section 5.8.3, "Impacts on Worker Health and Safety–Nonradiological." For further clarification, the definitions of illness and injury and examples of each subcategory are listed below.

OCCUPATIONAL INJURY. An occupational injury is any injury such as a cut, fracture, sprain, amputation, etc., that results from a work-related event or from a single instantaneous exposure in the work environment.

OCCUPATIONAL ILLNESS. An occupational illness is any abnormal condition or disorder, other than one resulting from an occupational injury, caused by exposure to factors associated with employment. It includes acute and chronic illnesses or disease, which may be caused by inhalation, absorption, ingestion, or direct contact. The seven illness categories with examples for each category are as follows:

- Occupational skin diseases or disorders: contact dermatitis, eczema, or rash caused by primary irritants and sensitizers or poisonous plants; oil acne; chrome ulcers; chemical burns or inflammations.

- Dust diseases of the lungs (pneumoconiosis): silicosis, asbestosis and other asbestos-related diseases, coal worker's pneumoconiosis, byssinosis, siderosis, and other pneumoconiosis.

- Respiratory condition due to toxic agents: pneumonitis, pharyngitis, rhinitis or acute congestion due to chemicals, dust gases, or fumes; farmer's lung.

- Poisoning (systemic effects of toxic materials): poisoning by lead, mercury, cadmium, arsenic, or other metals; poisoning by carbon monoxide, hydrogen sulfide, or other gases; poisoning by benzol, carbon tetrachloride, or other organic solvents; poisoning by insecticide sprays such as parathion and lead arsenate; poisoning by other chemicals such as formaldehyde, plastics, and resins.

- Disorders due to physical agents (other than toxic materials): heatstroke, sunstroke, heat exhaustion, and other effects of environmental heat; freezing, frostbite, and effects of ionizing radiation (isotopes, X-rays, radium); effects of nonionizing radiation (welding flash, ultraviolet rays, microwaves, sunburn).

- Disorders associated with repeated trauma: conditions to repeated motion, vibration, or pressure, such as carpal tunnel syndrome; noise-induced hearing loss; synovitis, tenosynovitis, and bursitis, and Raynaud's phenomena.

- All other occupational illnesses: anthrax, brucellosis, infectious hepatitis, malignant and benign tumors, food poisoning, histoplasmosis, coccidioidomycosis.

C-7.3 Health and Safety Implications of New Site Activities

Under the *Closure* Case, several activities would be performed that are different in either scope or magnitude (or both) than activities that have been performed historically at the Site. In general, these activities are more construction-intensive than the primary activities performed in the recent past and have a different set of hazards associated with them. Some of these activities and the hazards and expected injuries associated with them are described below.

Heavy equipment would be used in environmental remediation efforts and for construction of specific treatment processes. Building construction activities would be necessary for new waste treatment processes and waste storage facilities. Dismantling and demolition activities for building closures would require abatement and removal of contaminants as well as dismantlement and removal of large structural components. These construction activities would primarily involve subcontractors. The hazards presented by these new activities are likely to result in a higher rate of physical injuries than previous Site activities. Illnesses and exposures from the environmental contamination are expected to be minimal.

Heavy equipment operations for environmental remediation activities would result in increased potential for accidents and injuries. However, the private industry incidence rate for construction (13.6%) used to estimate recordable cases may be overly conservative because DOE-enforced contractor-implemented safety and health programs at the Site typically result in lower injury rates than for general industry.

The most common hazards expected fduring DD&D are those that cause slips, trips, and falls, which are typical of the construction industry. Examples of these hazards include tripping hazards from electrical cables, machine pinch points, and falls from scaffolding. Site safety and health requirements and procedures would be strictly enforced during this proposed activity, which would minimize injuries.

Low-temperature thermal desorption are proposed for the *Closure* Case for the treatment of environmental restoration waste. Most of the volatile gases are captured and treated prior to their release. Some of the gases are destroyed in the process. Very few exposure hazards are expected during the processes. The highest potential for injury or illness would occur in the construction of the facilities.

Buildings containing asbestos and beryllium would undergo abatement prior to decommissioning and demolition. Appropriate measures to protect against exposure would be implemented through the beryllium protection program and the carcinogen control program outlined in the Site Health and Safety Practices Manual. The potential for inhalation exposures during contaminant removal activities is anticipated to be low, because subcontractors removing the contaminants would used appropriate levels of respiratory protection. Other controls include dust and fiber suppression using surfactants and high volume air scrubbers with high-efficiency particulate air filters. Measures to prevent airborne releases to the surrounding environment include containment of the area prior to abatement, use of negative air enclosures, and encapsulation of the abated area prior to demolition. Injuries would be most likely to occur during the physical dismantling activities and the demolition phases.

Bibliography

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West 1985	West Publishing Company. *Natural Resource Law.* 1985.

PLEASE EXCHANGE THESE PAGES WITH THE PAGES IN THE CUMULATIVE IMPACTS DOCUMENT:

PAGE #	CHANGE WITH PAGE #
Executive Summary Page 1 & 2	Executive Summary Page 1 & 2
Page 2-7 & 2-8	Page 2-7 & 2-8
Page 2-11 & 2-12	Page 2-11 & 2-12

1/585

Department of Energy

ROCKY FLATS FIELD OFFICE
P.O. BOX 928
GOLDEN, COLORADO 80402-0928

JUN 10 1997

97-DOE-05028

Dear Community Member,

I am pleased to send you the Rocky Flats Cumulative Impacts Document (CID). The CID has been prepared to provide an updated baseline of the cumulative impacts to the worker, public, and environment due to Site operations, activities, and environmental conditions in light of the Site's change in mission. Specifically, the Site has gone from production of nuclear weapons components to materials and waste management, accelerated cleanup, reuse, and closure of the Site.

In addition, this document projects the cumulative impacts to the worker, public, and environment due to implementing the draft Site Closure Plan, dated February 1997. The draft Site Closure Plan is a planning tool for achieving accelerated cleanup and closure of the Site. The draft Site Closure Plan also includes the planning assumptions which are expected to reduce the overall site risks to the worker, public, and environment.

The analyses addresses five Site program areas, including Special Nuclear Materials Management, Facility Disposition, Waste Management, Environmental Restoration, and Site Support Services. Please note that shipment of plutonium metal, oxides, and residues to the Savannah River Site is only one option of several under consideration.

The Site will use the information contained in the CID to provide the data required to make decisions as prescribed by regulatory requirements. Public involvement will remain a cornerstone of our decision-making process in any case, and we will make every effort to involve you in the process.

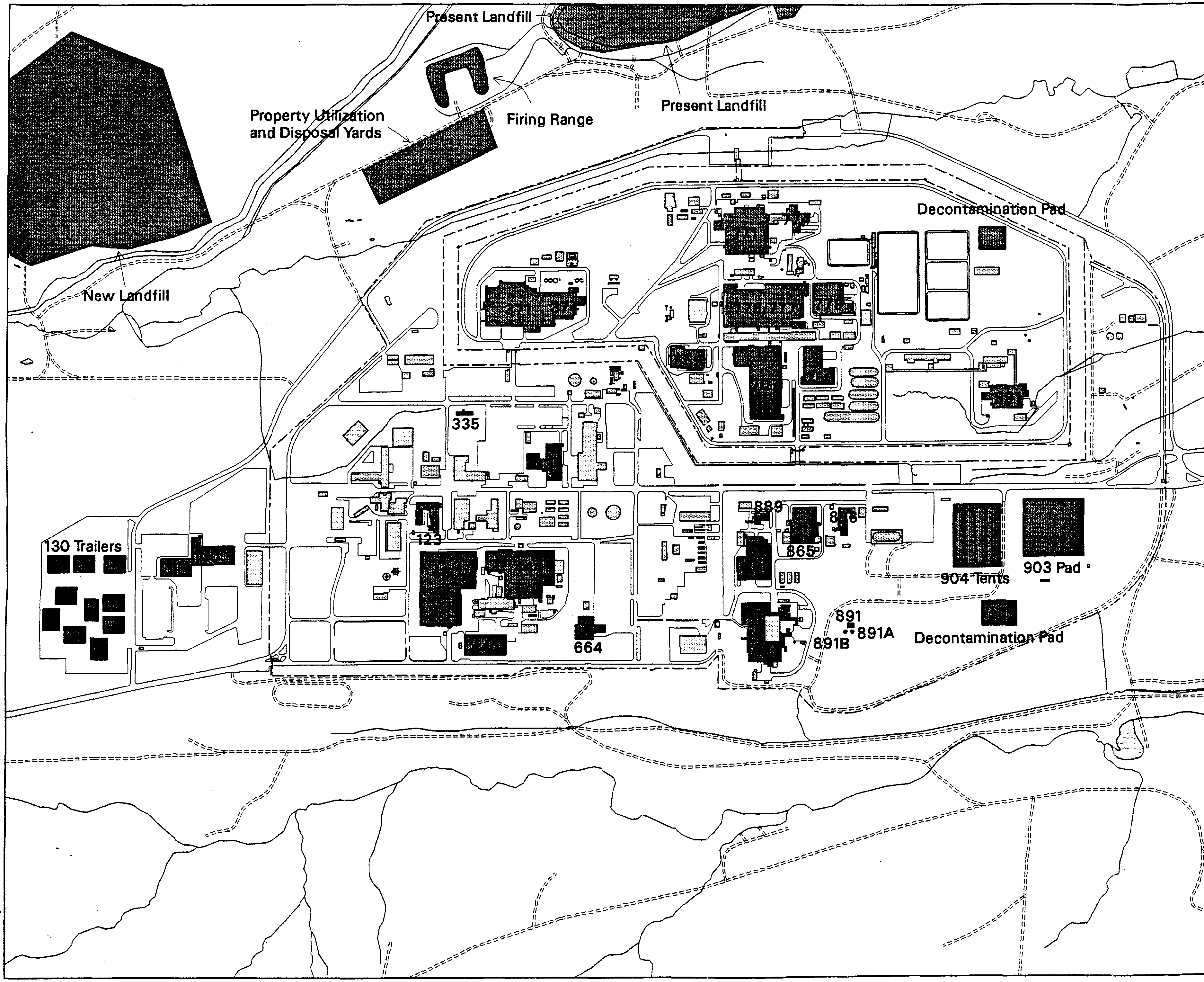
Should you have any questions regarding the CID, please contact Reg Tyler at 966-5927 or Mariane Anderson at 966-6088.

Sincerely,

Jessie Roberson

Jessie M. Roberson
Manager

1



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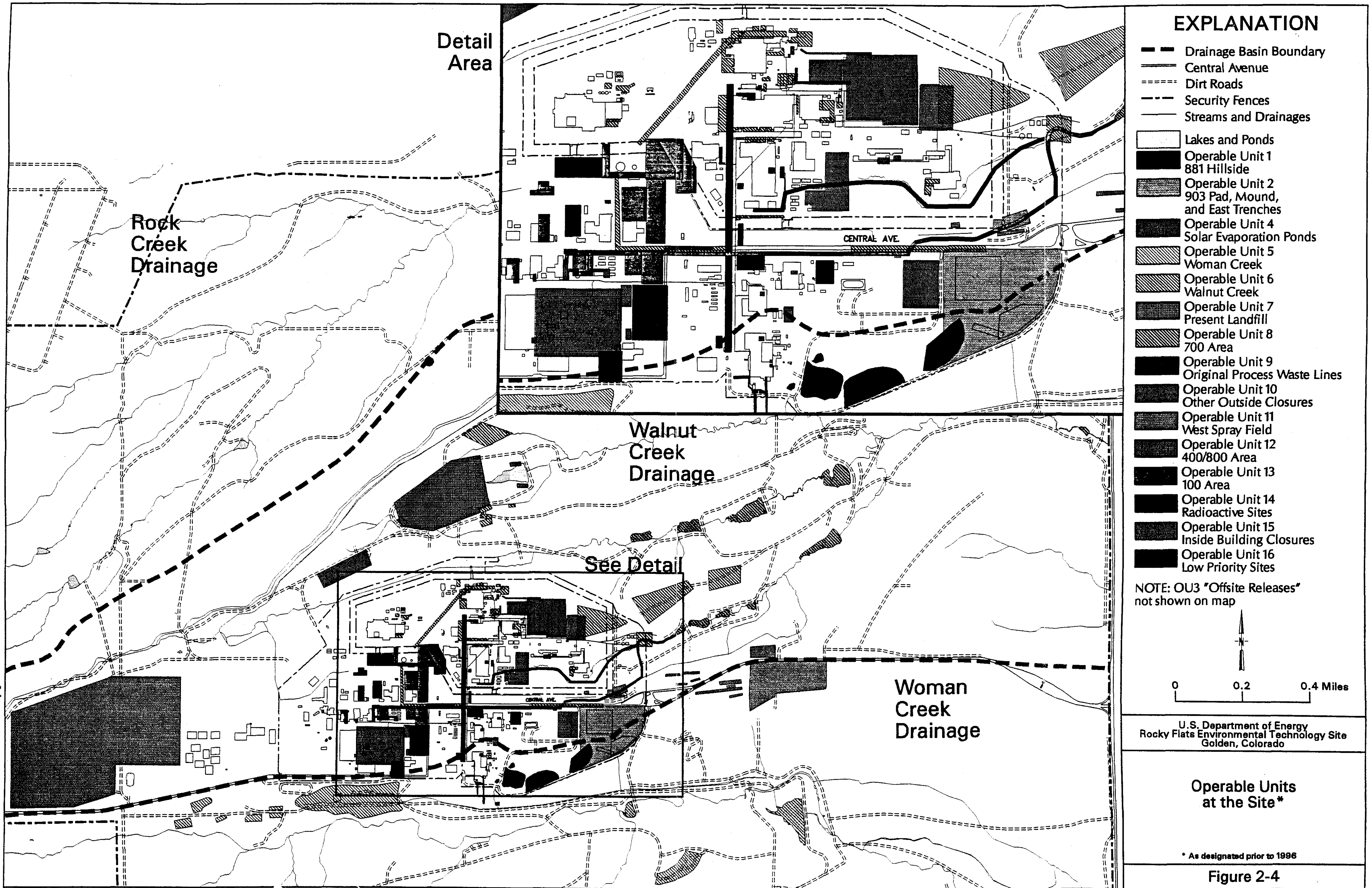
Rocky Flats Environmental Technology Site
Golden, Colorado

Key Facilities and Structures at the Site

Figure 2-3



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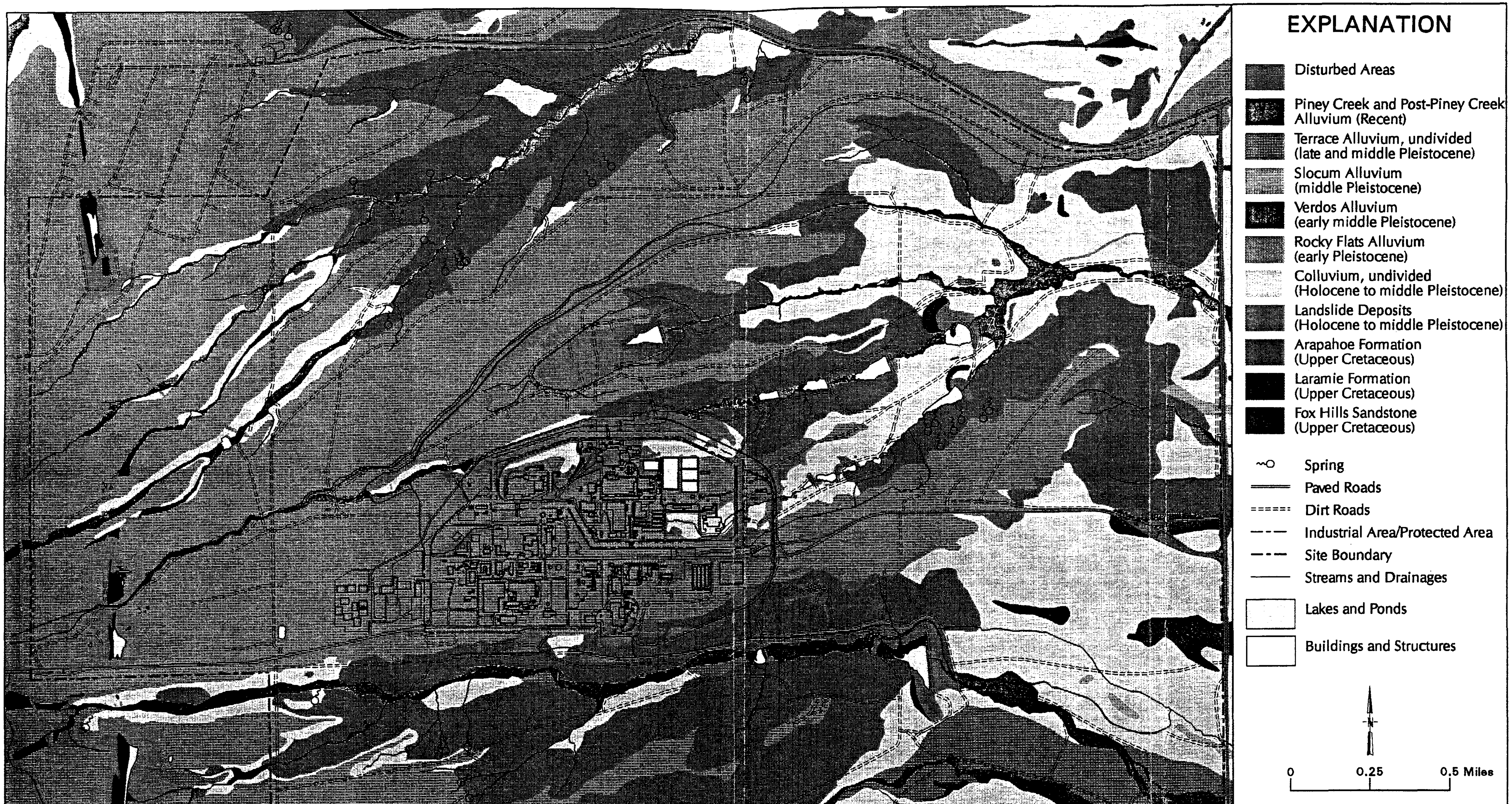
Operable Units at the Site*

* As designated prior to 1996

Figure 2-4

Best Available Copy

27-JUN-1996 GRA: $DATA3/sweis/support/maps/ihss.gra + AML: /export/home/data3/sweis/support cm.s/mainplot.aml



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Rocky Flats Environmental Technology Site
Golden, Colorado

Surficial Geologic Map of the Site and Vicinity

Source: Modified from USGS 1994

Figure 4.2-1

21-JUN-1996 GRA: $DATA3/sweis/support/m. s/geo.gra + AML: /home/data3/sweis/support/amls/mainplot.aml

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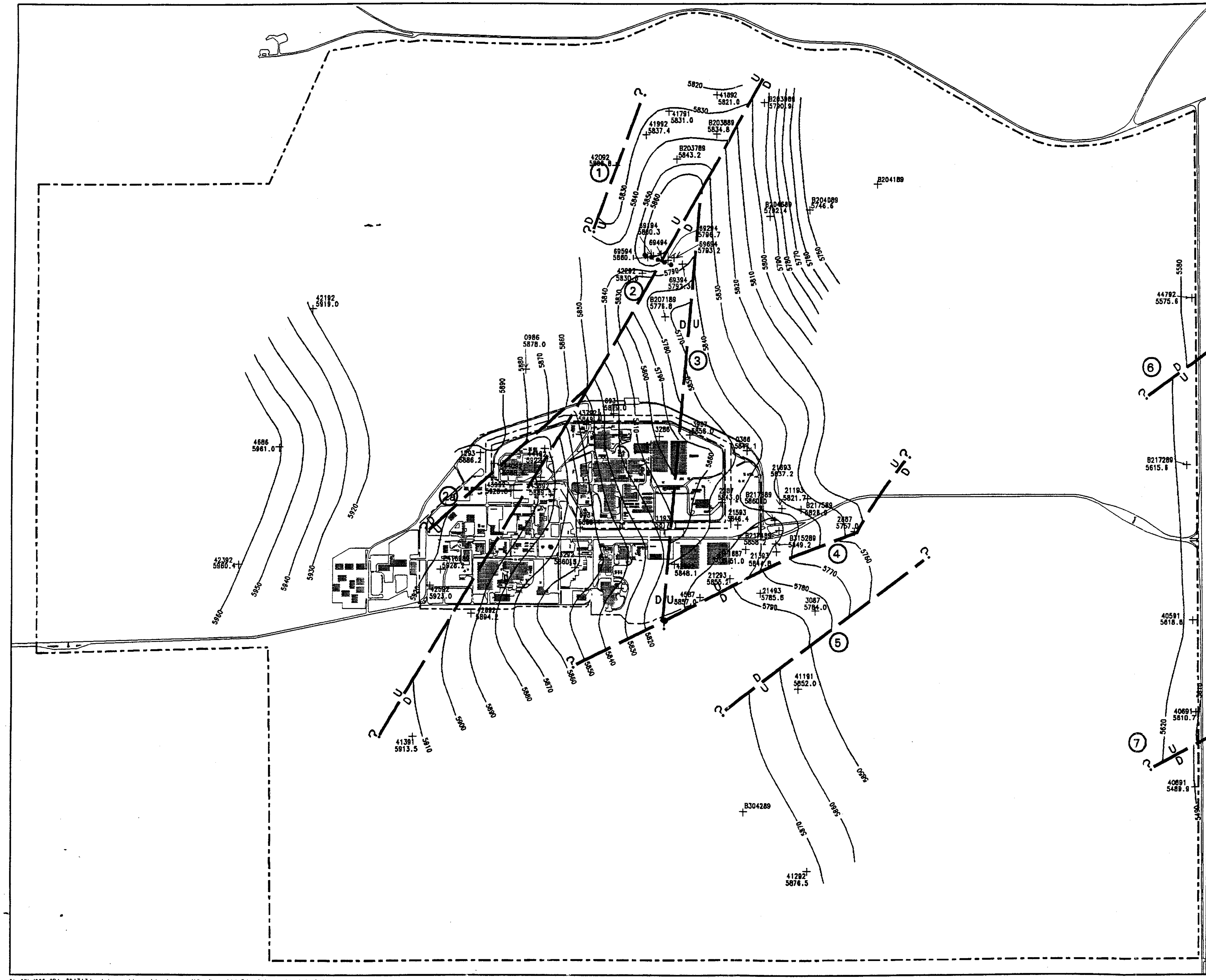

EXPLANATION

- ① Possible or Inferred Fault and Reference Number
- Trench Excavation
- Approximate Elevation of "A" Claystone Marker Bed
- "A" Claystone Elevation
- Paved Roads
- Dirt Roads
- Industrial Area/Protected Area
- Site Boundary
- Buildings and Structures

0 0.25 0.5 Miles

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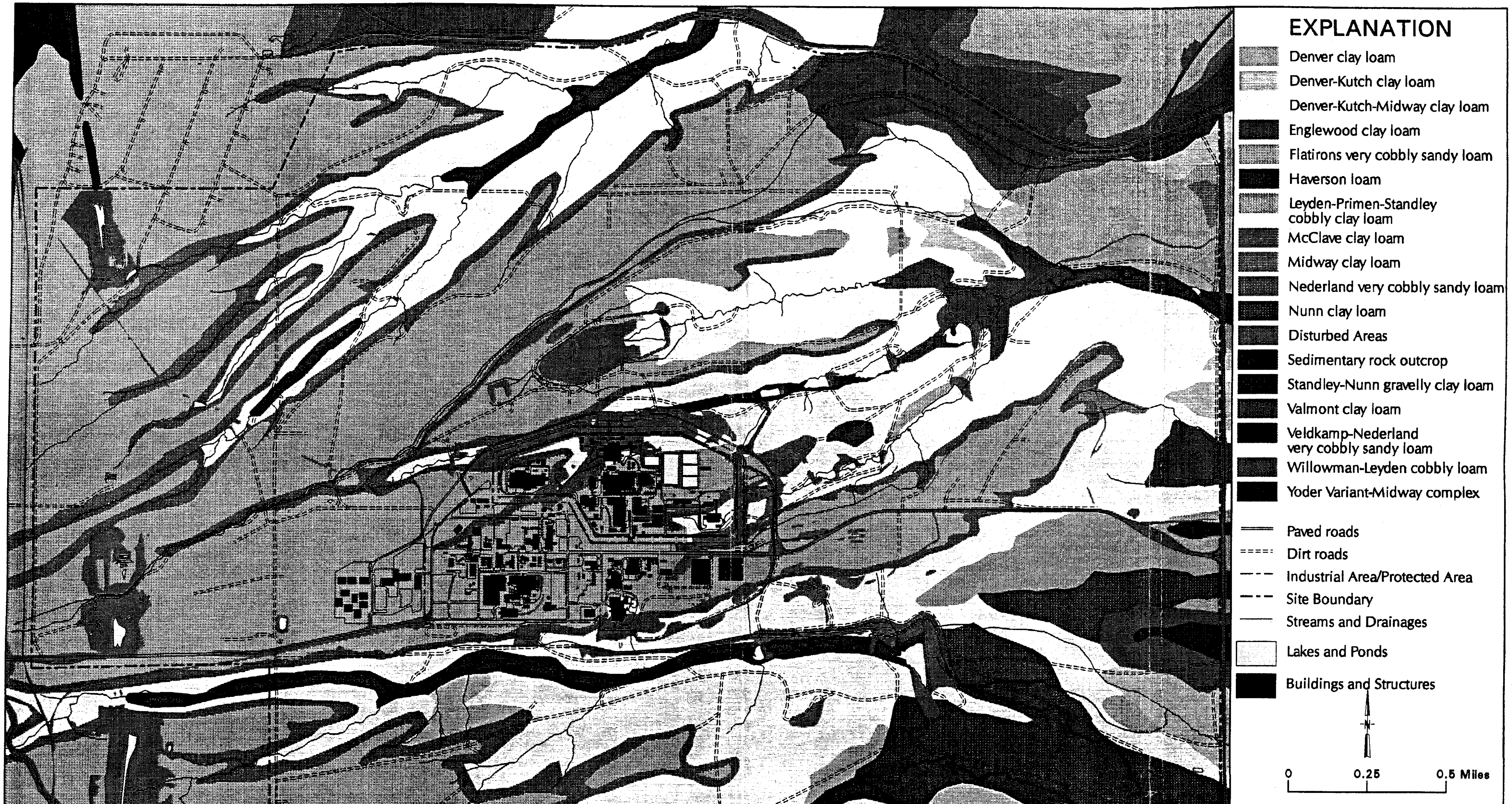
Rocky Flats Environmental Technology Site
Golden, Colorado

Approximate Location of Faults Underlying the Site

Figure 4.2-4

21-JUN-1996 GRA: $DATA3/sweis/support/maps/struct.gra • AML: /home/data3/sweis/support/amls/mainplot.aml



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Golden, Colorado

Soil Types
at the
Site and Vicinity

Source: Modified from SCS 1980

Figure 4.3-1

21-JUN-1996 GRA: $DATA3/sweis/support/maps/soil.gra • AML: /home/data3/sweis/support/ ...s/mainplot.aml

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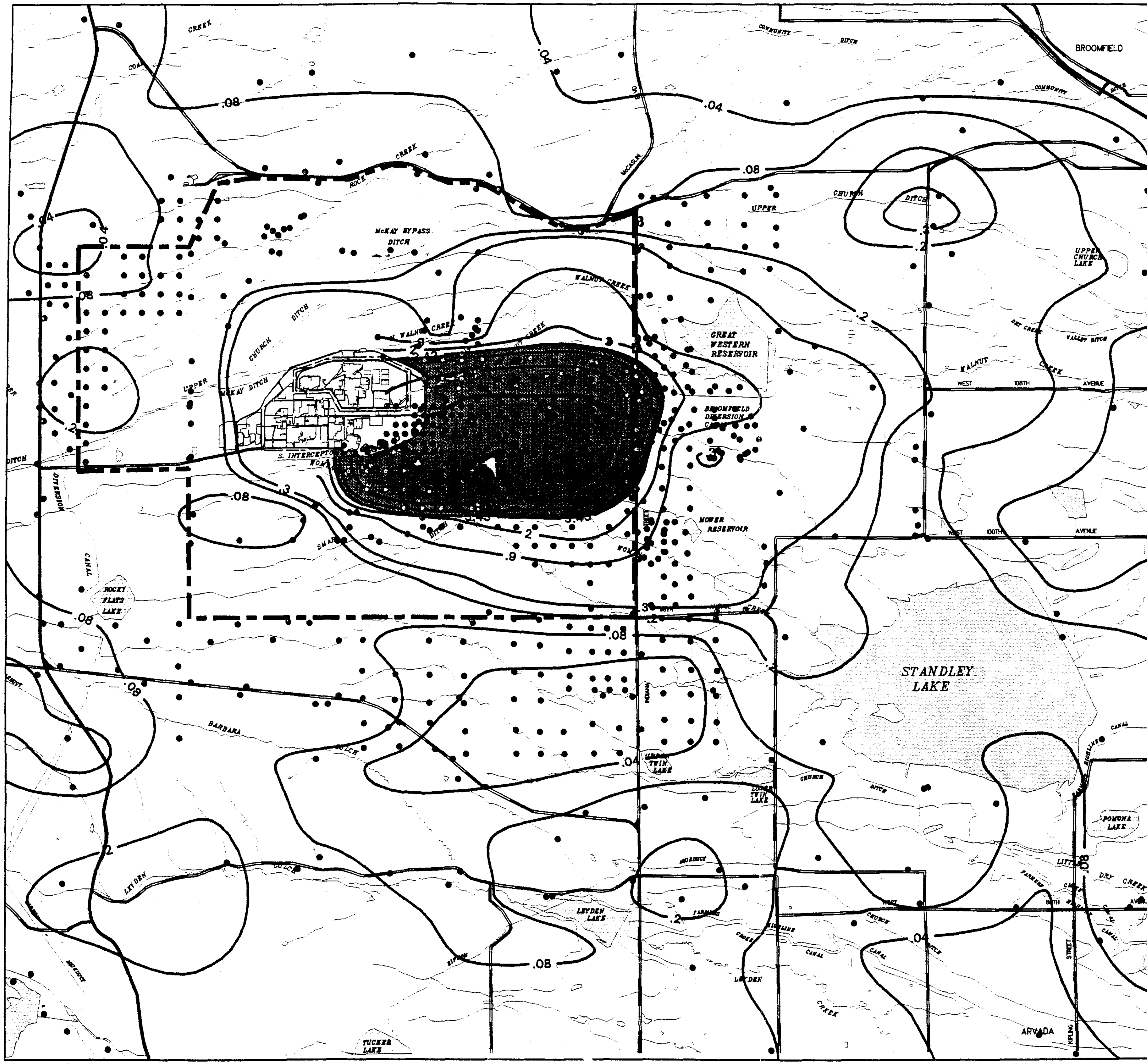

EXPLANATION

Pu 239,240 Concentration Levels (pCi/g)

- < 2
- 2 - 4.99
- 5 - 9.99
- > 10

Other

- Area where concentration is greater than 3.43 pCi/g
- Isoconcentration Lines
- Major Roads
- Secondary roads
- Industrial Area/Protected Area
- Site Boundary
- Streams and Drainages
- Lakes and Ponds

0 0.5 1 Miles

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Golden, Colorado

Plutonium Concentrations in Soils Surrounding the Site

Figure 4.3-2

21-JUN-1996 GRA: $DATA3/sweis/support/maps/pusoil.gra • AML: /home/data3/sweis/support/amls/mainplot.aml

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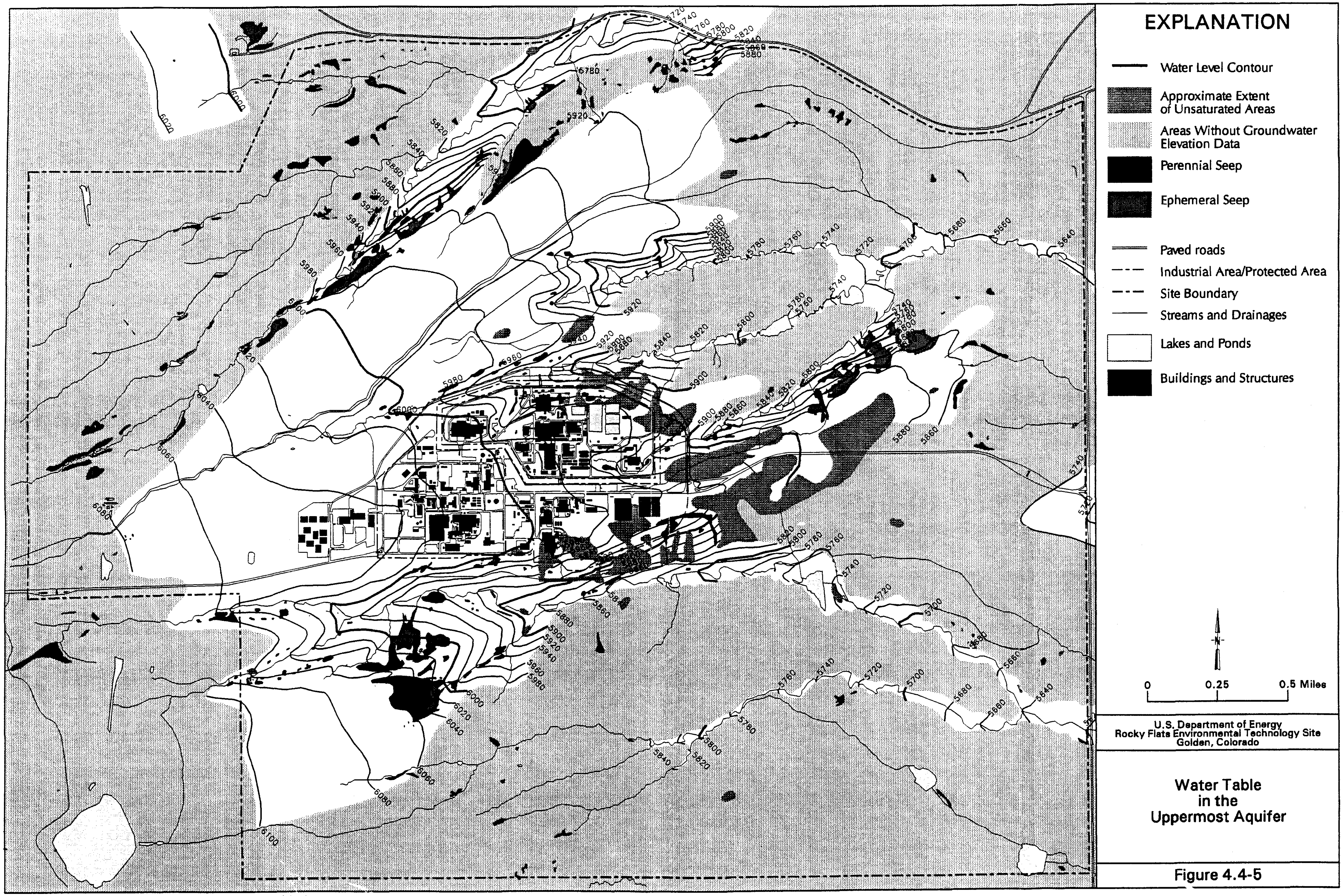

Water Table in the Uppermost Aquifer

Figure 4.4-5

21-JUN-1996 GRA: $DATA3/sweis/support/maps/poten.gra • AML: /home/data3/sweis/support/amls/main .ml

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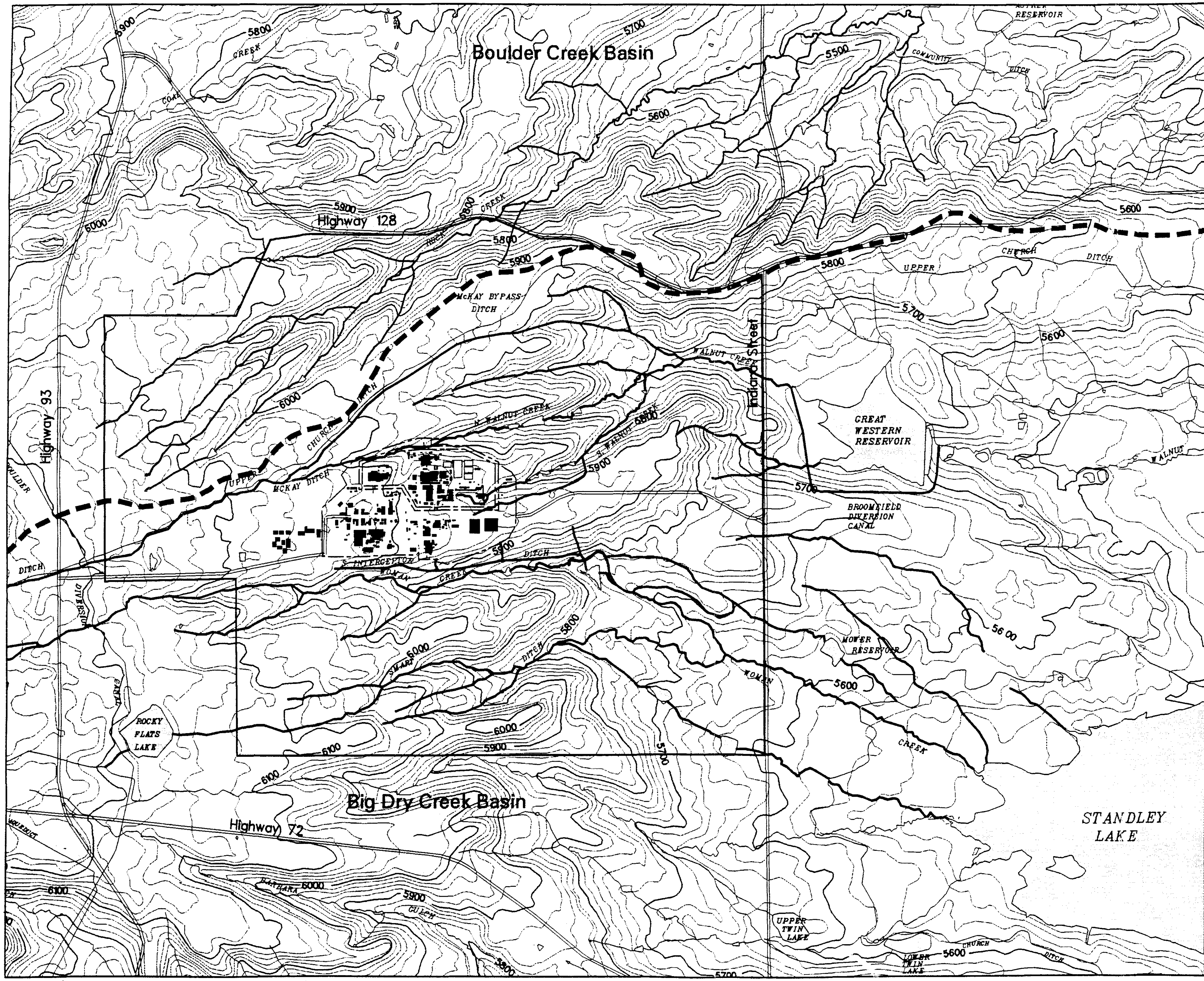

EXPLANATION

- Drainage Basin Boundary
- Rock Creek Drainage
- Walnut Creek Drainage
- Woman Creek Drainage
- Other Streams and Drainages
- Topographic Contours
- Roads
- Industrial Area/Protected Area
- Rocky Flats Environmental Technology Site Boundary
- Lakes and Ponds
- Buildings and Structures

0 0.5 1 Miles

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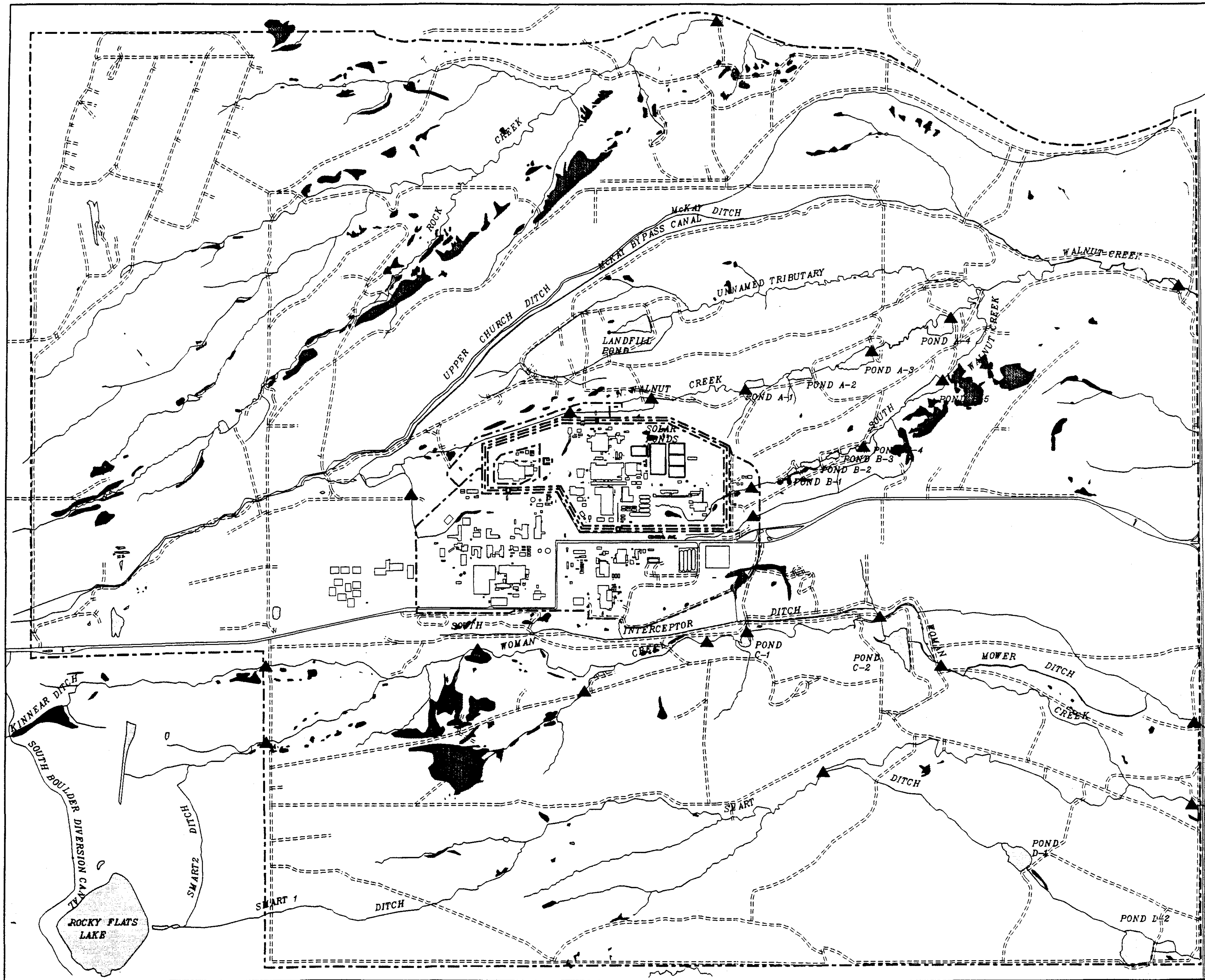
Golden, Colorado

Drainage Basins in the Site and Vicinity

Figure 4.4-8

21-JUN-1996 GRA: $DATA3/sweis/support/maps/dbasin + AML: /home/data3/sweis/support/amls/dbasin.aml



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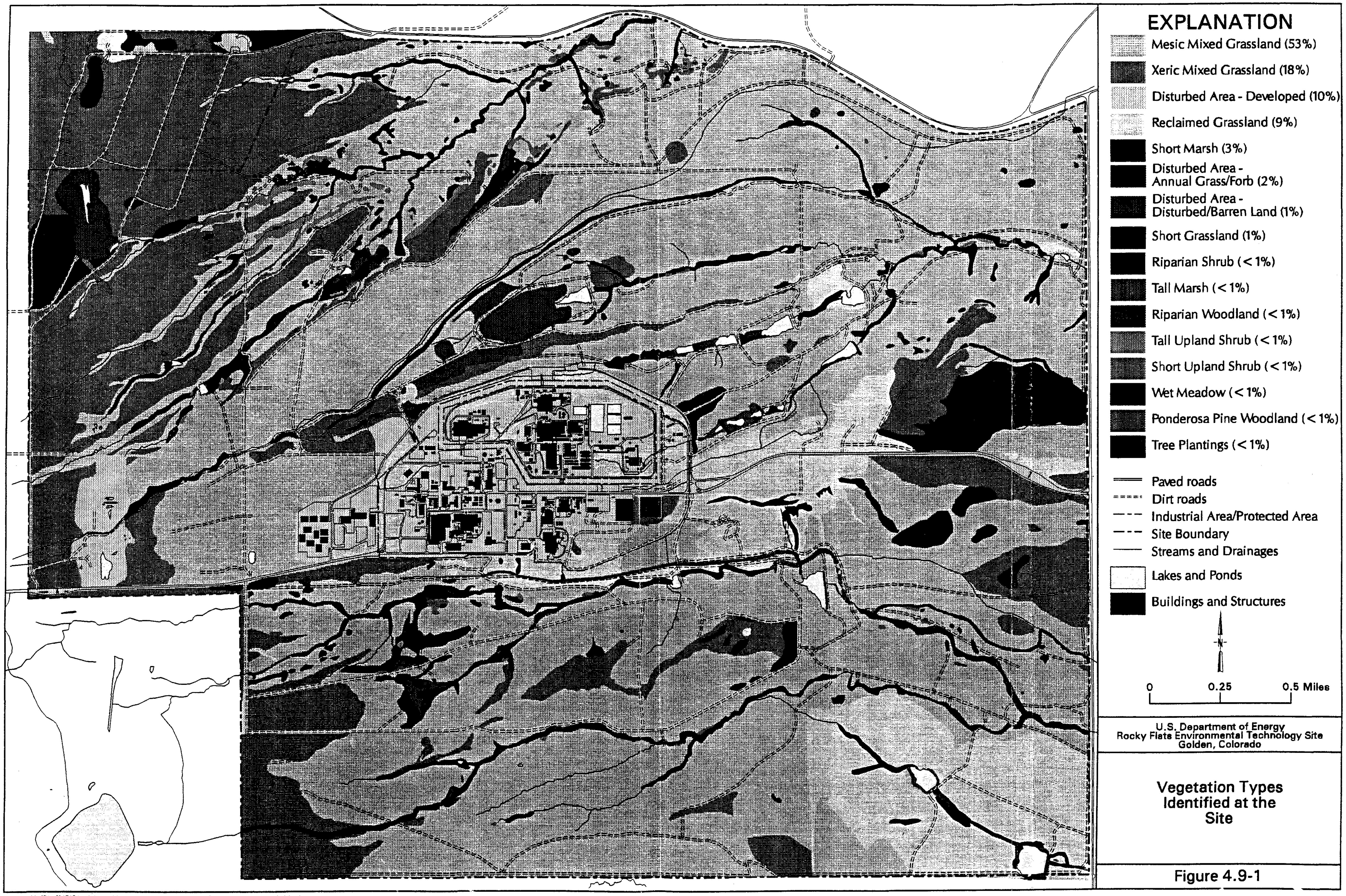
Golden, Colorado

Locations of Seeps, Ponds, and Event-Related Surface Water Monitoring at the Site

Figure 4.4-10

21-JUN-1996 GRA: $DATA3/sweis/support/maps/sw.gra • AML: /home/data3/sweis/support/amls/mainplot.aml



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Vegetation Types Identified at the Site

Figure 4.9-1

21-JUN-1996 GRA: $DATA3/sweis/support/maps/veg.gra + AML: /home/data3/sweis/support/amls/mainplot.aml

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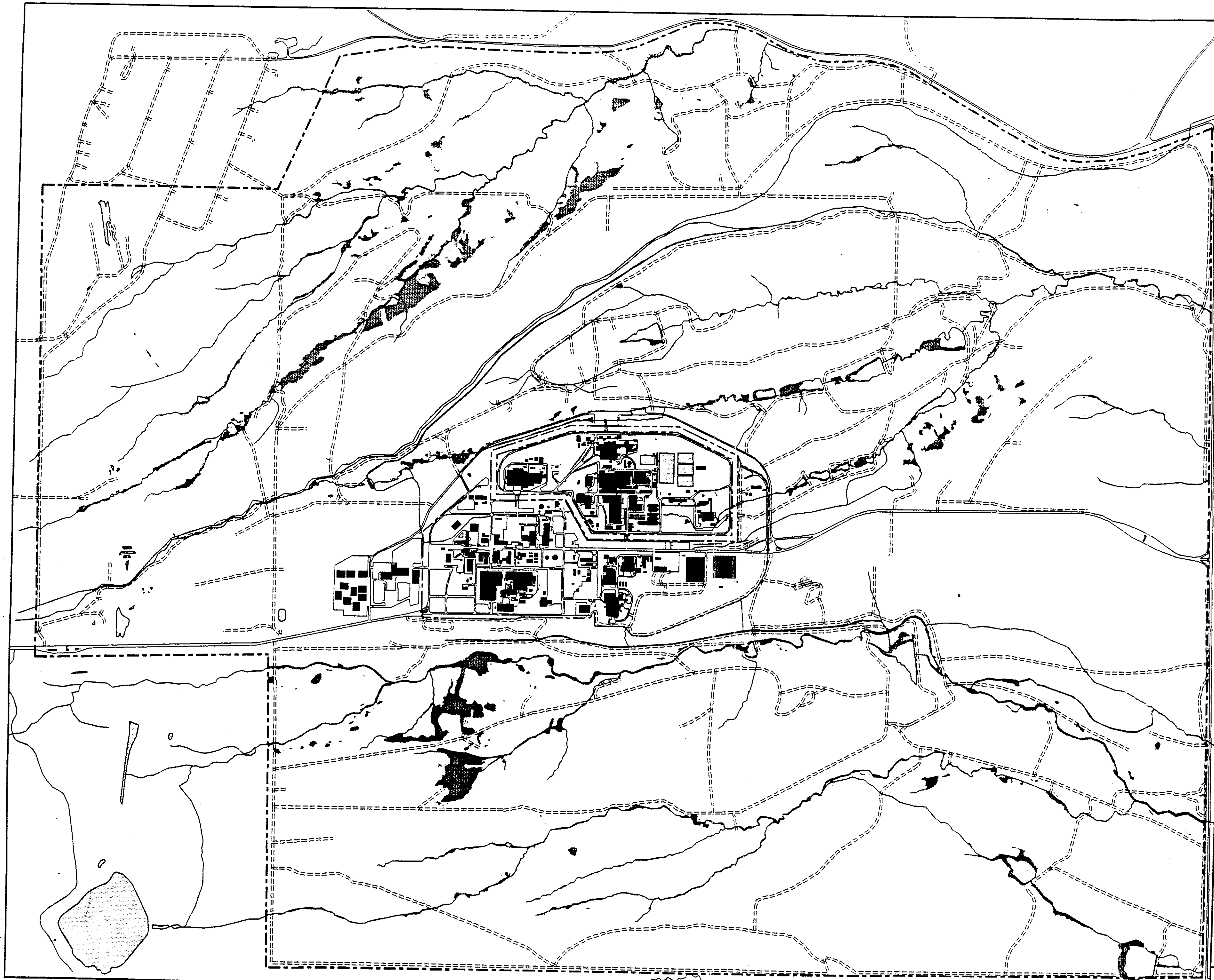

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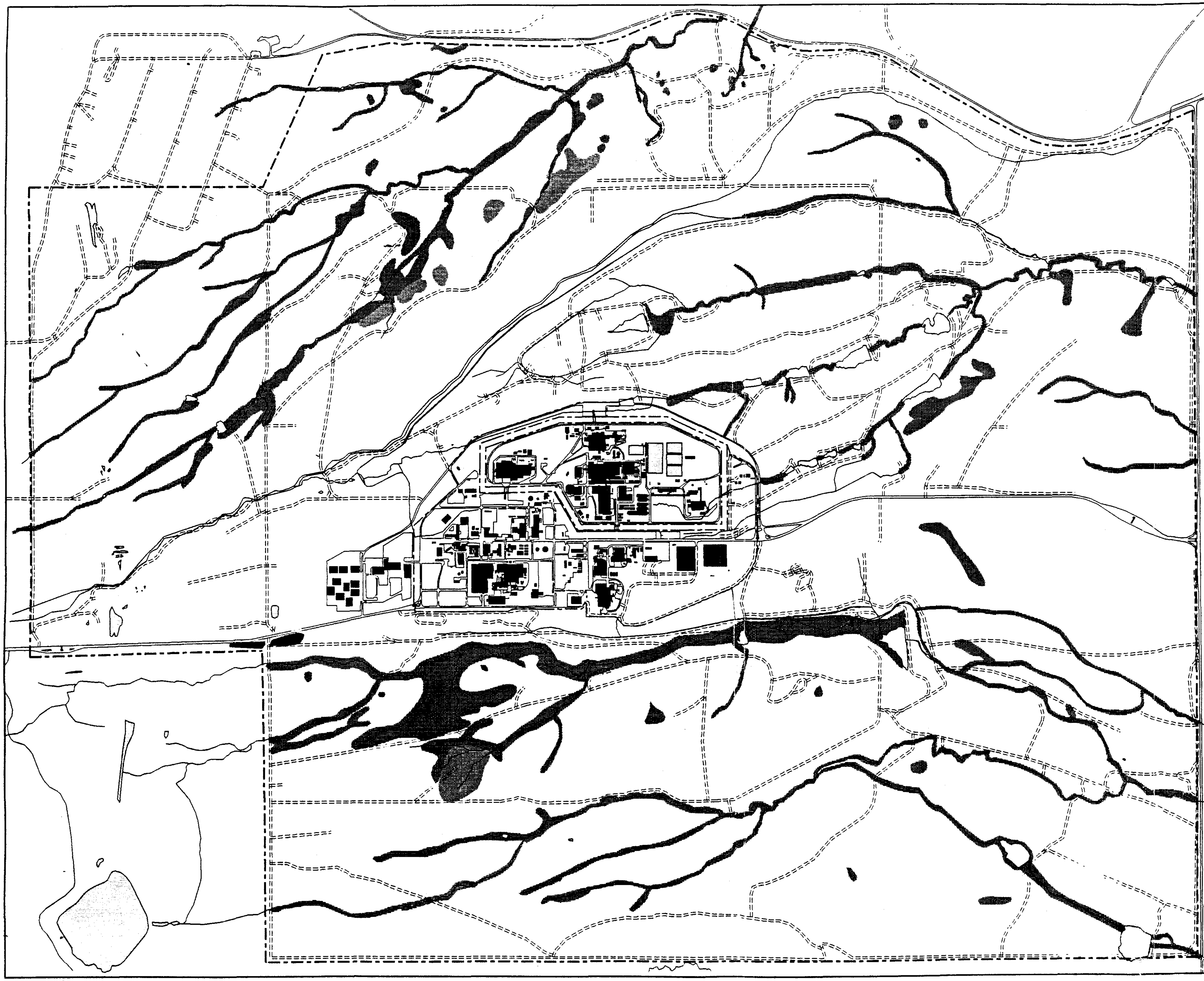
Jurisdictional Wetlands Identified at the Site

Source: Wetland areas as identified by EG&G as of November 22, 1994.

Figure 4.9-2

21-JUN-1996 GRA: $DATA3/sweis/support/maps/wet.gra • AML: /home/data3/sweis/support/amls/mainplot.aml



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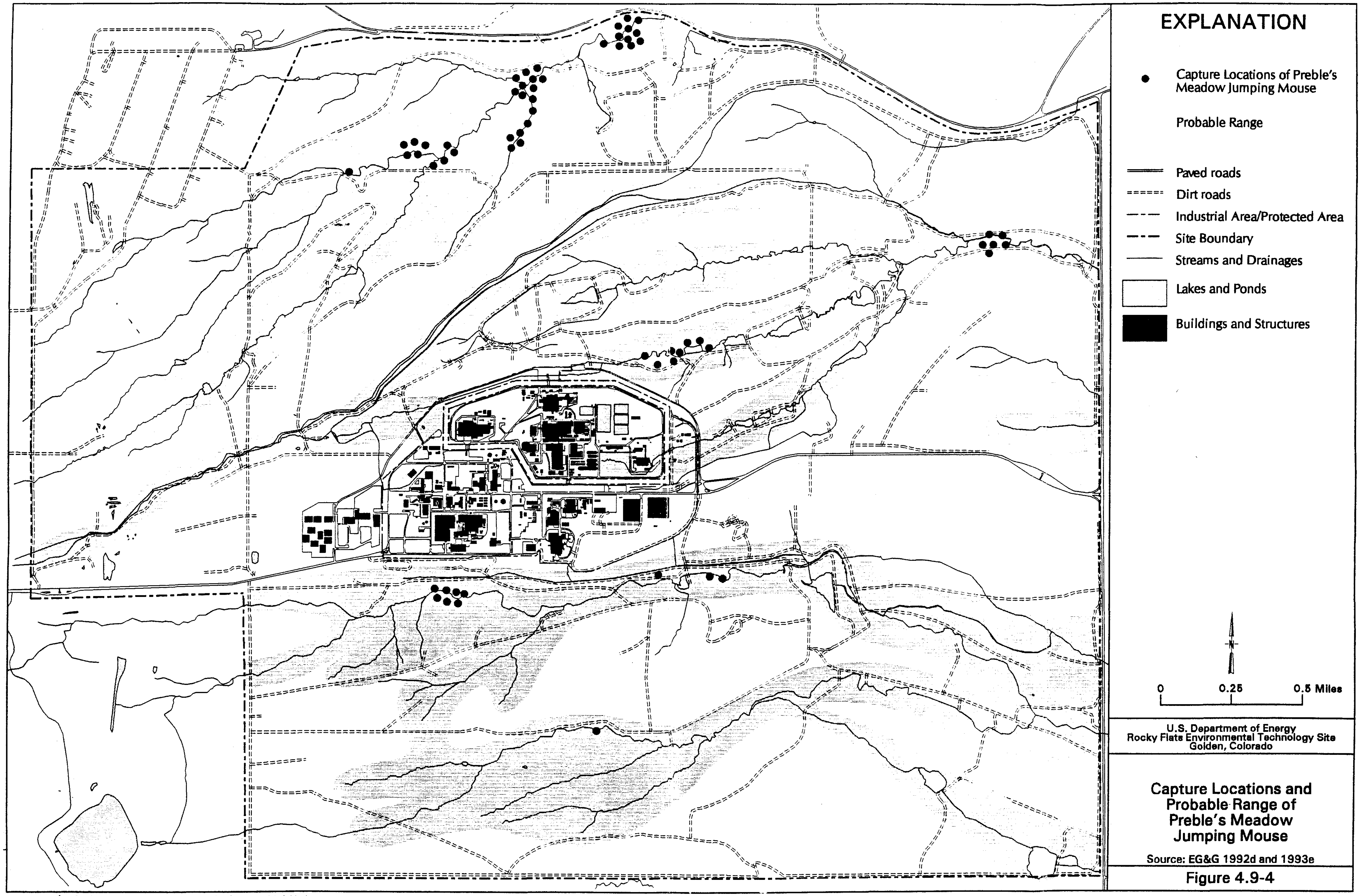
Areas Surveyed for Ute Ladies-Tresses and Forktip Three-Awn

Source: EG&G 1993e

Figure 4.9-3

21-JUN-1996 GRA: $DATA3/sweis/support/maps/ute.gra * AML: /home/data3/sweis/support/amls/mainplo.aml

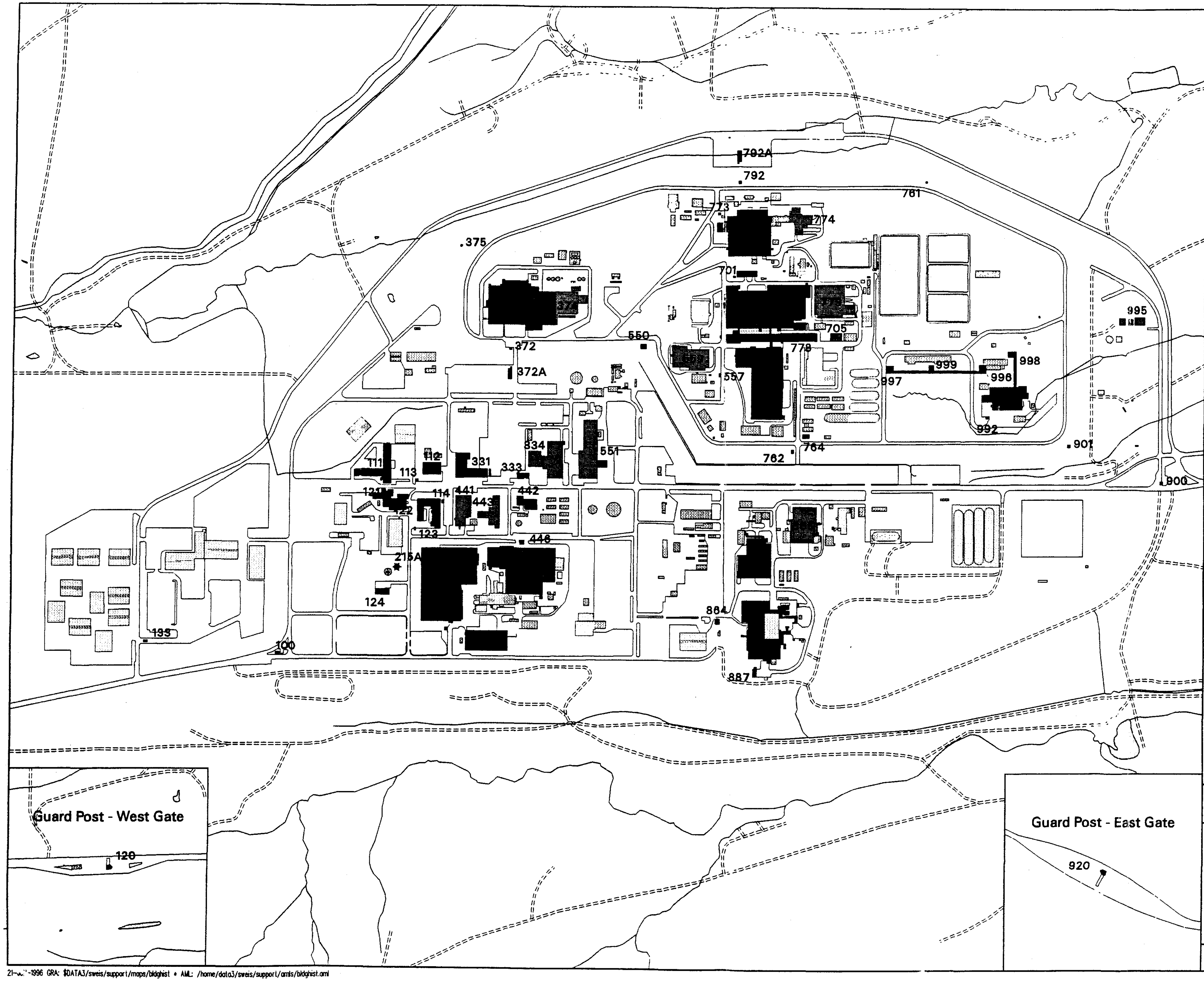


Capture Locations and Probable Range of Preble's Meadow Jumping Mouse

Source: EG&G 1992d and 1993e

Figure 4.9-4

21-JUN-1996 GRA: $DATA3/sweis/support/maps/preb.gra • AML: /home/data3/sweis/support/amls/mainplot.aml



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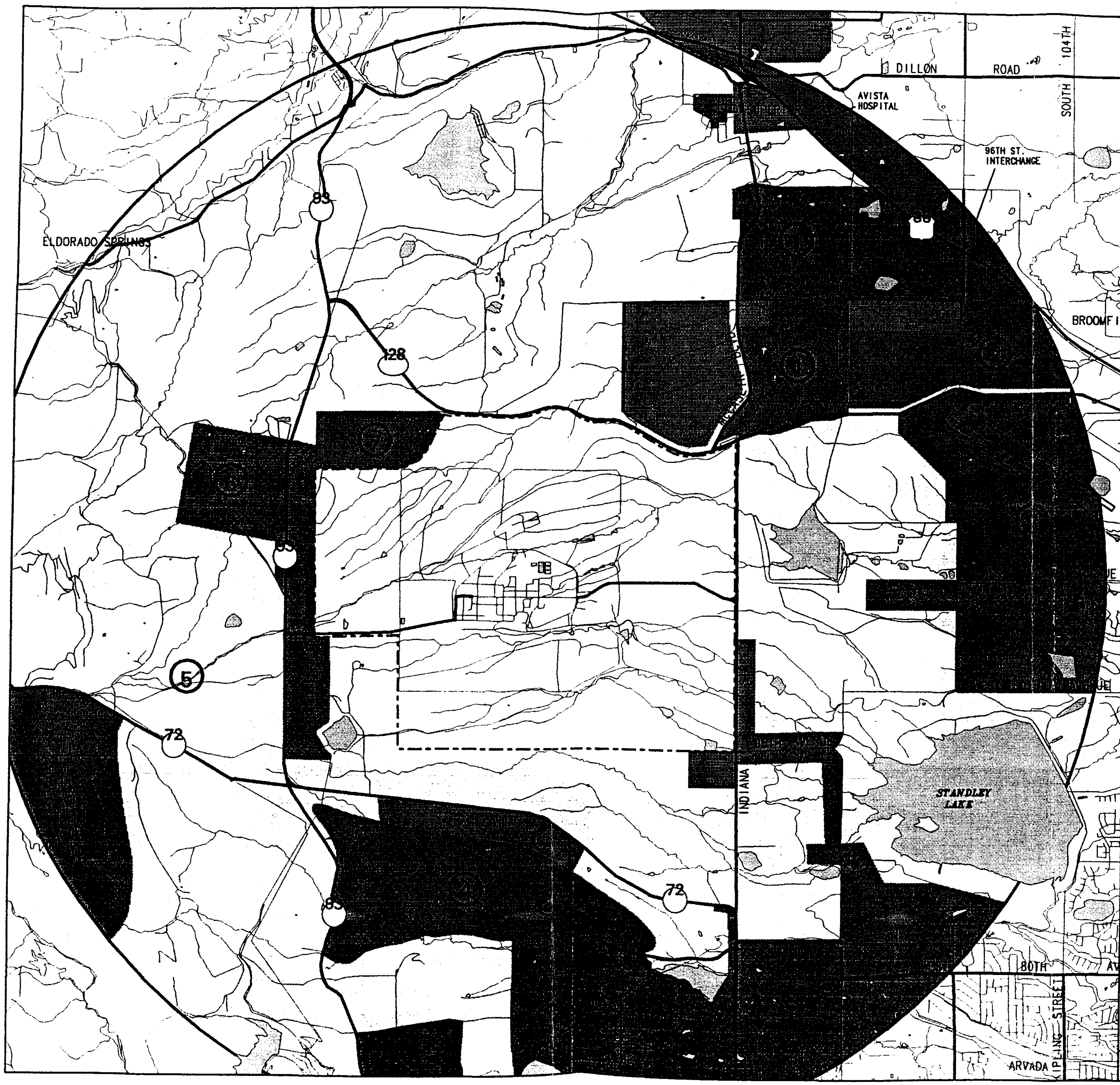
Locations of Cold War Era Resources in the Rocky Flats Historic District

Figure 4.10-1

21-...-1996 GRA: $DATA3/sweis/support/maps/bldghist • AML: /home/data3/sweis/support/amls/bldghist.aml



EXPLANATION

- 5-Mile Radius from the site
- Primary Roads
- Secondary Roads
- Site Boundary
- Streams and Drainages
- Lakes and Ponds
- Current/Planned Open Space (Recreational Area/Preserve/ Interspersed Residential/Ranchland)
- Current/Planned Residential
- Current/Planned Mixed Use (Light Commercial and/or Residential)
- Current/Planned Business Park/Special Use
- Current/Planned Mining

1. Rock Creek residential development - Town of Superior
2. Interlocken business park, golf course, and hotel - City of Broomfield
3. Jefferson County Airport - City of Broomfield
4. Jefferson County Landfill
5. Jefferson County Open Space
6. Mining by Western Aggregates - Jefferson County
7. National Renewable Energy Laboratory Wind Site

N

0 0.5 1 Miles

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Rocky Flats Environmental Technology Site
Golden, Colorado

Current and Planned Land Use Activities Surrounding the Site

Figure 5.15-1.